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The Middle Ordovician Tellico-Sevier Syncline: A Stratigraphic, Structural and Paleoseimic Investigation.

Stephen Christopher Whisner
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a dissertation written by Stephen Christopher Whisner entitled "The Middle Ordovician Tellico-Sevier Syncline: A Stratigraphic, Structural and Paleoseimic Investigation.." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Geology.

Robert D. Hatcher, Jr., Major Professor

We have read this dissertation and recommend its acceptance:

William M. Dunne, Hugh H. Mills, Kenneth H. Orvis

Accepted for the Council:
Dixie L. Thompson

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Vice Chancellor and
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A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Stephen Christopher Whisner
August 2005

DEDICATION

I would like to dedicate this Dissertation to my family, my wife and my sons.

ACKNOWLEDGEMENTS

There are many people, without whose help this dissertation would not have been completed. I would like to thank all the members of the Structure and Tectonics research group whom I have watched come and go in the time I have been here. At one time or another they have all helped with thoughts, questions or comments which have added to the research presented here. I would like to thank Dr. Peter Lemiski, Harry Moore and Jeff Munsey for their help and guidance in the field and for coming up with different research locations outside of established mapping area. I would like to thank the members of my Dissertation committee, Dr. Ken Orvis, Dr. Hugh Mills, Dr. Bill Dunne, and Dr. Rick Williams. I would like to thank Dr. Robert D. Hatcher, Jr. for his help, guidance, and patience during the completion of this dissertation. I would like to thank Nancy Meadows who has kept the entire office running smoothly, made my life easier with her encouragement and help, listened to problems with a knowing ear and only had kind words to say about everyone. I would also like to thank my family for their many years of support and encouragement. Finally, I would like to thank my wife, Jennifer, who while keeping me from turning into a pile of sniveling goo(see Whisner, 1998), is also a fantastic structural geologist, field partner, sounding board for ideas, graphic artist, technical consultant, math whiz, and a great mom to our two (so far) sons.

ABSTRACT

Analyses of remote-sensing satellite data, aerial photography, radar images, and digital elevation models, and detailed (1:24,000-scale) geologic mapping of bedrock and surficial deposits were conducted in a portion of the southeastern Tennessee. This area contains the southern portion of the Tellico-Sevier Alleghanian syncline and the highest concentration of modern earthquakes as well as two major rivers with unconsolidated floodplain and terrace deposits that would be most susceptible to disruption by earthquakes. Cambrian to Mississippian age rocks occurs in the syncline. The majority of detailed mapping was conducted in Middle Ordovician Chickamauga Group rocks.

Earthquakes occur in the East Tennessee seismic zone (ETSZ) with greater frequency than anywhere east of the Rocky Mountains outside of the New Madrid seismic zone and the Charlevoix region in Canada. No earthquakes greater than M = 4.9 have been recorded in the ETSZ, although the observation window of historical seismic activity is narrow. It is possible that large earthquakes have occurred in the past. The identification of two sites in or near the modern ETSZ with anomalous and potentially earthquake-related deformed Quaternary sediments underscores the need for continued study to properly assess the seismic hazard of this zone.

Bedrock and surficial geologic mapping did not produce unequivocal evidence of earthquake-related neotectonic deformation. The geologic map constructed between the Little Tennessee and Tellico Rivers does, however, reveal several previously undocumented stratigraphic and structural geometries.

A new stratigraphic column has been developed for the southern portion of the Tellico-Sevier syncline in sufficient detail to separate potential Quaternary paleoseimic features from both Alleghanian deformation and depositional-related features such as paleosinkholes or facies changes. The stratigraphic column also unifies the previously

terminology for Paleozoic units. This column uses established rock unit names that, although they do not conform to current state geologic map terminology, more accurately represent the rocks present in the southern portion of the Tellico-Sevier syncline.

The Chapman Ridge Sandstone was studied in particular detail. It has never been mapped as a discrete unit over such a large area; so only a few 1:24,000-scale geologic maps separate it from the Holston Formation. Facies and unit thicknesses in the Chapman Ridge vary across and along its outcrop belt. It is less cross bedded, less ferruginous, and thinner to the south. The Chapman Ridge is thinner in the southeastern limb and thicker in northwestern limb of the Tellico-Sevier syncline. Cross-bed orientation measurements were collected at over 50 stations between Tennga, Georgia, and Mascot, Tennessee, to determine paleocurrent vectors to investigate paleodispersal. These data reflect a weak though discernable pattern of regional current directions (south-southeast) and sediment dispersal.

The Tellico-Sevier syncline formed during Alleghanian deformation in the hanging-wall of the Chestuee/Dumplin Valley thrust sheet. Interpretation of seismic reflection data and forward modeling suggest the northwest limb of the future syncline was later modified by out of sequence duplexing in the underlying Saltville sheet, creating the southeastern limb. Continued movement of the Blue Ridge thrust sheet further deformed the southeastern limb of the syncline. Shortening attributable to the Chestuee and Dumplin Valley faults, folding, and faulting in the syncline may be ~42 km. Backthrusting in the southern limb of the Kyker Bottoms folds thins the Athens shale. Generation of the Belltown folds near Tellico Plains, Tennessee and associated faults are more complex than was originally thought, and may point to a relationship with faulting further southwest.

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CHAPTER 1

INTRODUCTION

Purpose of Study

This dissertation was originally intended to determine if any record of large Holocene earthquakes (M> 5.0) exists in sediments of a large river system within the modern East Tennessee seismic zone (ETSZ)(Fig. 1-1). The portion of the ETSZ where greatest earthquake frequency occurs was selected for detailed geologic mapping. Paleozoic rocks, Quaternary deposits, and modern flood plains were mapped to determine if evidence of paleoseismic occurs here. This area extends from Vonore, Tennessee, to Tellico Plains, Tennessee, and contains one of the largest non-impounded river systems within the ETSZ, the Tellico River, as well as the Little Tennessee River. The Vonore, Tennessee area was also chosen because it is near the epicenter of the 1987 **M**=4.2 earthquake, one of the largest recorded modern earthquakes in the ETSZ. Structures were mapped at multiple scales to attempt to separate Paleozoic bedrock deformation from deformation related to Quaternary earthquakes. Geologic mapping was supplemented by analysis of satellite imagery, aerial photographs, radar images, and digital elevation models, in the search for paleoseismic evidence.

The scope of the project was expanded as geologic mapping revealed inconsistencies in previous mapping of the area, and differences in the interpretation of Middle Ordovician stratigraphy. Additional tasks included compiling a detailed geologic map of the Tellico–Sevier syncline from Etowah, Tennessee, to Du Pont, Tennessee from all previous workers; reinterpreting the stratigraphic section to define more uniform mappable lithostratigraphic units throughout the syncline based on previous work along with the most recent mapping; and reevaluation of the basin model focusing on the Chapman Ridge Sandstone.

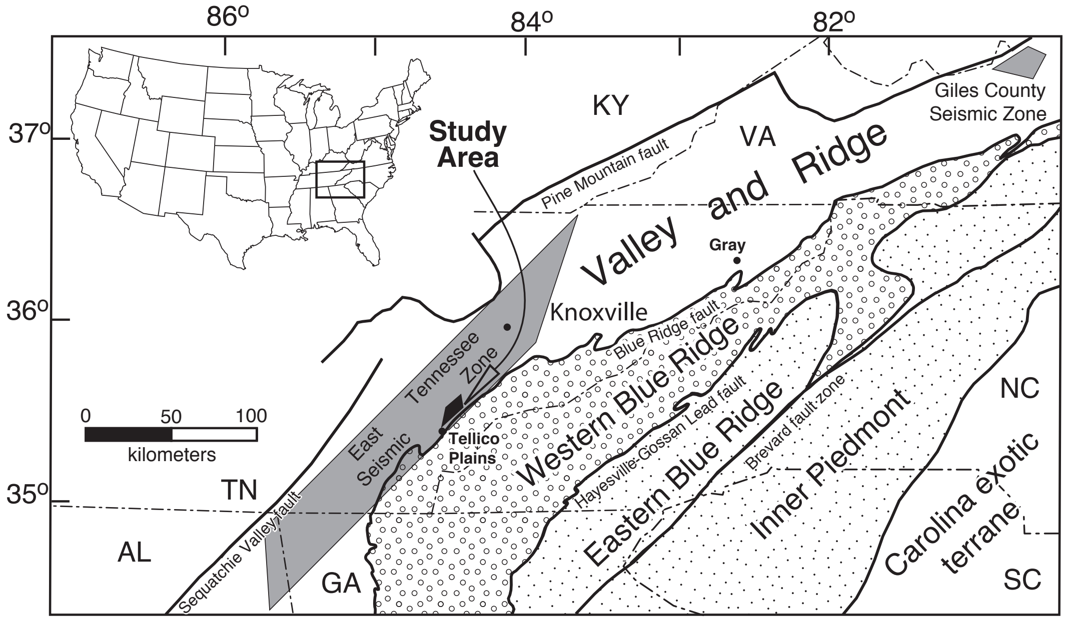


Figure 1-1. Location of the East Tennessee seismic zone relative to the major geologic provinces of the southern Appalachians. Provinces other than the Valley and Ridge are patterned. (Base map from Hatcher et al., 1990.)

Geologic Setting

The Tellico-Sevier syncline in eastern Tennessee is comprised of Paleozoic rocks deformed during the Alleghanian orogeny. Within the study area, some 5 km of folded and faulted early to middle Paleozoic rocks (Rodgers, 1953) are underlain by Grenvillian crystalline basement (Hatcher et al., 1987). The Paleozoic cover consists of Cambrian through Mississippian rocks in the footwall of the Great Smoky fault. These rocks are part of the broad Tellico-Sevier syncline, which extends from Etowah, Tennessee, northeastward to the northern end of Chilhowee Mountain near DuPont, Tennessee, where it becomes a broad synclinorium traceable to the Virginia border. The syncline plunges gently northeast and is cored by Middle Ordovician carbonate, sandstone and siltstone, Devonian-Mississippian shale, and lower Mississippian shale and siltstone in the hanging wall of the Chestuee, Dumplin Valley, and Saltville fault (Fig.1-2). This syncline contains the primary record of the middle Ordovician Blountian basin, classically described as the foredeep created during the Taconic orogeny (Bayona and Thomas, 2004).

The Little Tennessee and Tellico Rivers (Fig. 1-3), flowing west-northwest, have deposited Holocene fluvial sediments on this structure and modified the landscape. These fluvial sediments were the target for locating recognizable paleoseismic evidence.

The ETSZ lies along a 180 million-year-old passive margin in the Appalachian Valley and Ridge (Fig. 1-3). It comprises an area of seismic activity 300 km long by 50 km wide, paralleling the Appalachian Mountains, stretching from near the Virginia border to the northeast to the Georgia/Alabama border at its southwestern end (Fig. 1-1). Instrumentally located focal depths of all earthquakes in the ETSZ lie not in the Paleozoic rocks of the fold-thrust belt, but in crystalline bedrock well below the Alleghanian (late Paleozoic) master décollement at depths ranging from ~8 to 25 km (Chapman et al., 1997). Most earthquakes occur east of the geopotential New York-Alabama lineament

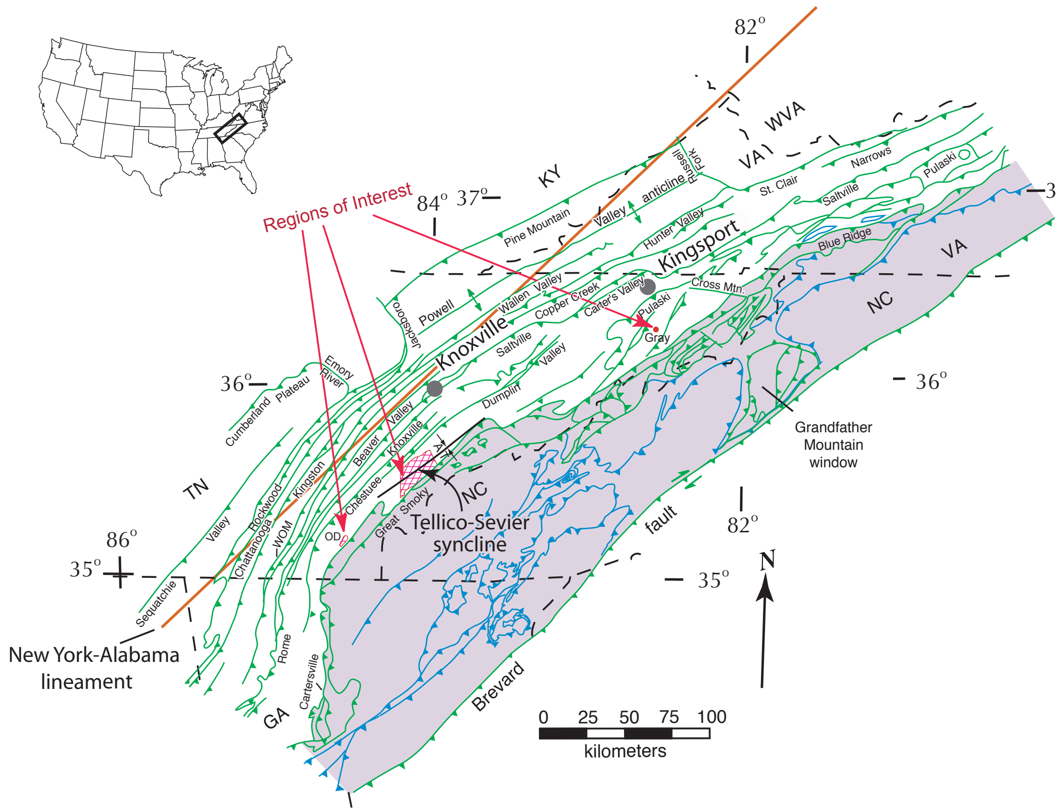


Figure 1-2. Location of areas of interest. (Cross hatch = Detailed map area, OD= Oswald Dome landslide). Major Valley and Ridge faults in green. Orange line is New York-Alabama lineament. WOM=Whiteoak Mountain fault, AT=Axial Trace. (Modified from Hatcher et al., 1990.)

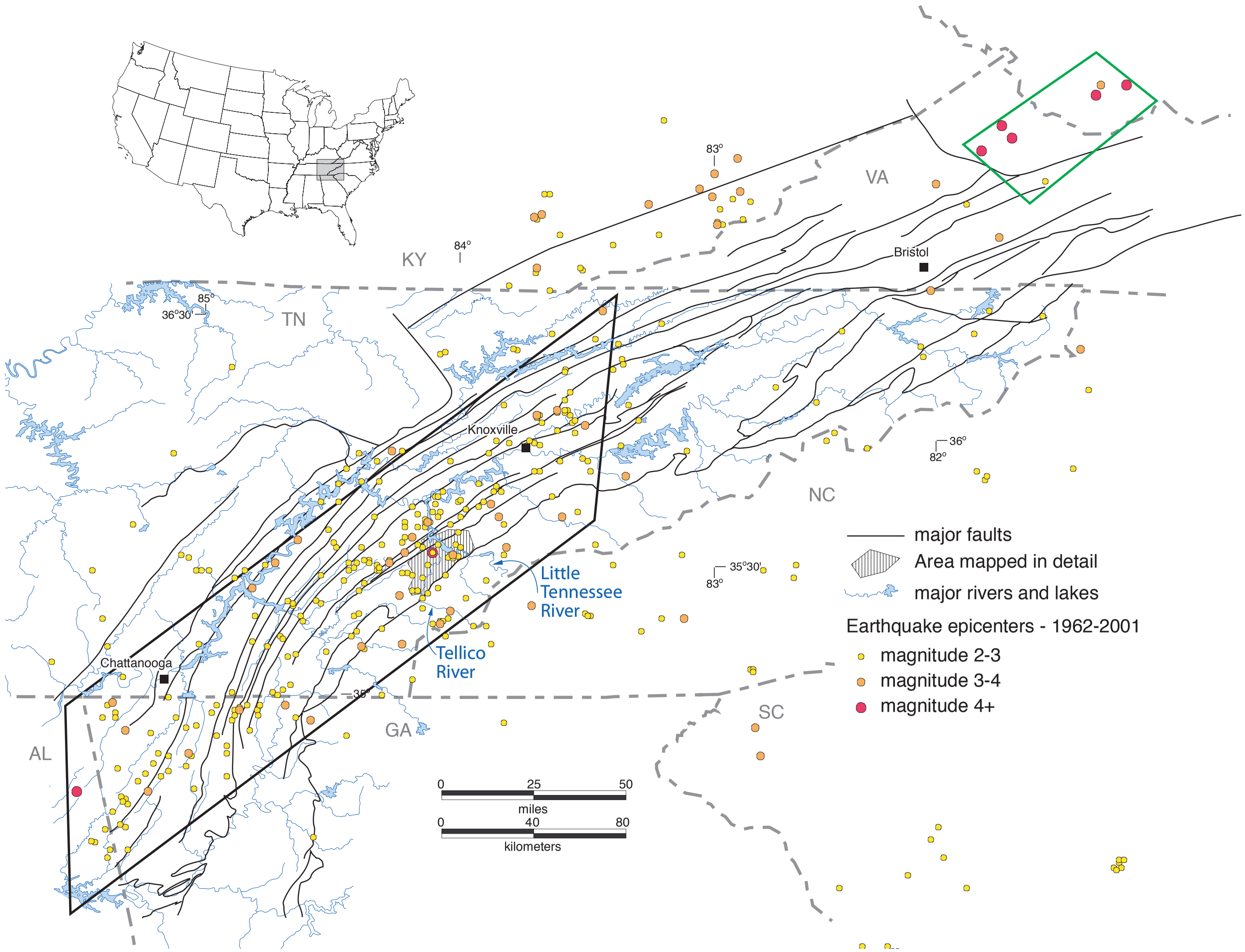


Figure 1-3 The general outline of the East Tennessee seismic zone (black rhomboid), Giles County Seismic zone (green polygon), recent earthquake locations (plotted from Southern Appalachian Regional Seismic Network data) and major faults in the Valley and Ridge physiographic province. (Base map from Whisner and Hatcher, 2003.)

(King and Zeitz, 1978) (Fig. 1-2), which has been interpreted as a suture between different types of basement rock within the Grenville orogen (Hatcher et al., 1987, 2004; Powell et al., 1994).

Study Area

The area mapped lies south of Vonore, Tennessee, along the Little Tennessee and Tellico Rivers (Fig. 1-2). It was chosen for its high seismic activity (Fig. 1-3) and many drainages with exposed floodplains. The mapped area includes portions of the Madisonville, Mount Vernon, Rafter, Tellico Plains, Tallassee, and Vonore 1:24,000-scale 7.5-minute quadrangles (Fig. 1-4) (Plate I and Plate III). A larger portion of the Tellico-Sevier syncline was compiled from geologic maps by Rodgers (1953), Neuman (1955), King and Ferguson (1960), Neuman and Wilson (1960), Biery (1968), Wiener (unpublished), Kashfi (1971), Thigpen (2002), and Heath (2003), from Etowah, Tennessee, to the south to U.S. 321 to the north to show stratigraphic relationships and geometry of the Middle Ordovician syncline (Plate II).

Two other areas were mapped to determine if they contain evidence of paleoseismic activity. One is a sinkhole deposit near Gray, Tennessee, that was discovered in 1999 by the Tennessee Department of Transportation during road construction. While this site was outside of the initial proposed study area, the identification of possible paleoseismic features in what was thought at the time of its discovery to be a Pleistocene deposit led to its inclusion in this study (Fig. 1-3). The other area is a large landslide deposit on the northwestern slope of Oswald Dome near Benton, Tennessee (Fig. 1-3). This landslide is anomalously large for the south-central Appalachians (Mills, 2000). At the time it was thought this landslide might have been triggered by an earthquake (Jibson, 1996). After some weeks of study, however, it was determined to be a composite of many smaller fans, none of which provided unequivocal evidence of an earthquake triggered landslide, and therefore this portion of the study was

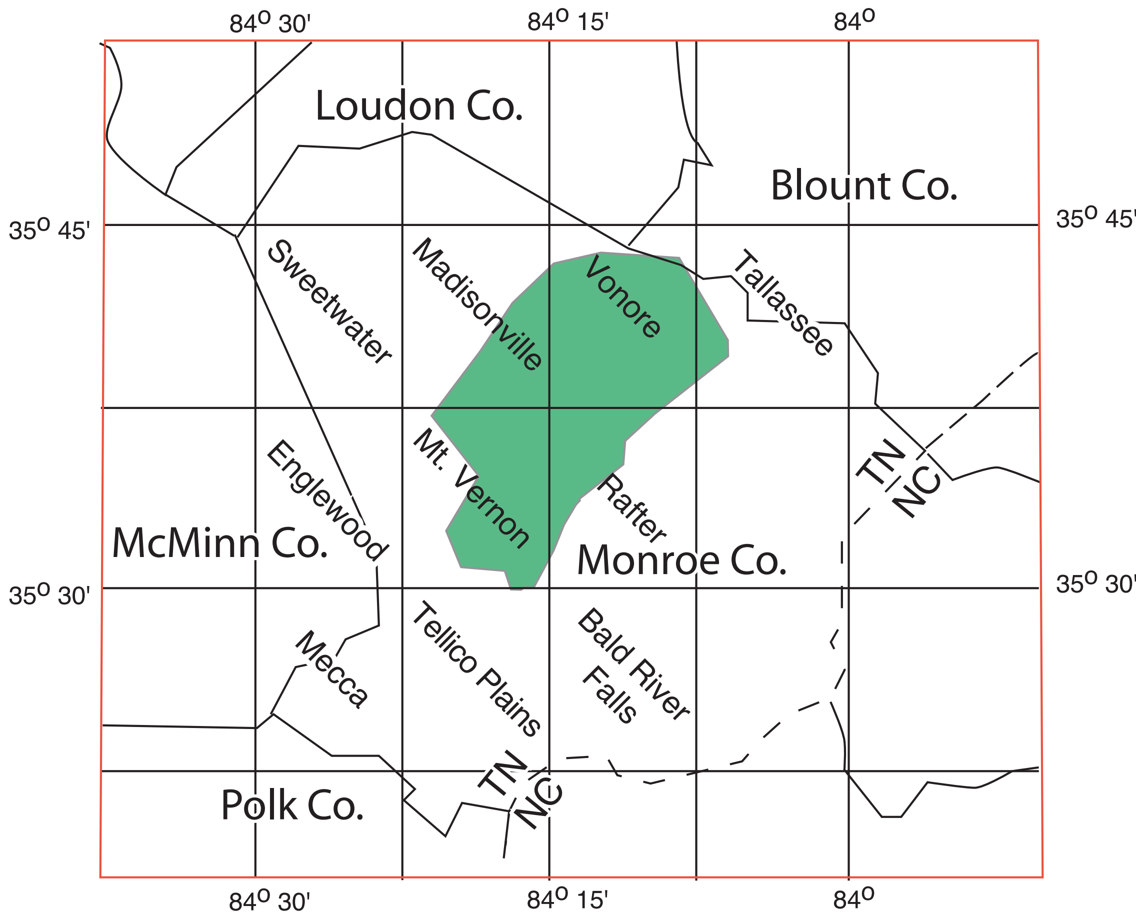


Figure 1-4. Location of parts of 1:24,000 scale quadrangles mapped in this study.

dropped.

Previous work (geologic mapping, geophysical work, and remote sensing) was incorporated into a plan to determine if the ETSZ is capable of a larger earthquake than has previously been recorded in this region (10 CFR Part 100, Appendix A, III, (g)). The most effective method of finding evidence of prehistoric earthquakes was determined to be detailed mapping of an area with a large amount of exposed unlithified deposits that would be susceptible to disruption by earthquake shaking (Obermeier, 1996) and that could be trenched for more detailed analysis. In East Tennessee, fluvial deposits (floodplains) of major rivers best meet these criteria. Unfortunately, most large rivers in the modern-day ETSZ have been dammed and their floodplains drowned. To address this problem, the selected field area contains both a river with a mostly drowned floodplain (Little Tennessee) and one with a well-exposed floodplain (Tellico) in the area of high modern earthquake activity (Fig. 1-3).

Chapman Ridge Sandstone

The Chapman Ridge sandstone in the Middle Ordovician Chickamauga Group is the first widespread deposit of coarse siliciclastic sedimentary rocks related to the Taconic orogeny in the Valley and Ridge of East Tennessee (Cattermole,1955). It is also the primary ridge former in the Tellico-Sevier syncline. It clearly outlines the shape of the syncline on topographic maps, aerial photographic, and space images. The Chapman Ridge became a primary focus of this research because it was mapped as a portion of the geologic base map of the study area. Concurrent work by other graduate students mapping other portions of the Tellico-Sevier syncline (Thigpen, 2002; Heath, 2003) as well as age dating by Bream (2003) prompted a more detailed look at the Chapman Ridge over its entire outcrop belt to determine if an updated model could be formulated of its source and role in Blountian basin evolution. A review of previous work on the Chapman Ridge showed that several workers had included it with other Middle Ordovician units as a sandy member of the Athens Shale (Swingle, 1959), sand lenses of the Holston marble (Rodgers, 1953), or sand stringers of the Ottosee and Sevier Shale (King, 1964). Mapping of the Chapman Ridge from its southernmost outcrops near Cisco, Georgia, to its northernmost outcrop revealed variability in grain size, cross bedding, changes in amount of siliciclastics and bed and unit thickness within the sandstones and sandy limestone of the Chapman Ridge but showed that it was a separable, mappable unit.

Structure of the Tellico-Sevier Syncline

The Tellico-Sevier syncline appears on the 1:250,000 scale geologic map of Tennessee (Hardeman et al., 1966) to be a relatively simple upright syncline. Mapping at 1:24,000 scale by the author and others (Thigpen, 2002; Heath, 2003) and cross-section construction projected to basement using forward computer modeling have revealed a more complexly deformed syncline. Quadrangle-scale folds and faults, along with changes in stratigraphic thickness in Middle Ordovician units comprising the syncline, add difficulty to constructing balanced cross sections through the syncline. Faulting and folding of the southeastern limb of the syncline is much greater than in the northwestern limb and is not fully understood. Possible out-of-sequence as well as possible retrocharriage (Heath, 2003), may make the southern limb a composite of Chapman Ridge and younger rocks continuous with the northern limb with Athens and older rocks thrust over creating what looks from above to be an unbroken succession of rock.

CHAPTER 2

STRATIGRAPHY

The East Tennessee Valley and Ridge contains Paleozoic bedrock with ages ranging from Cambrian through Pennsylvanian. The portion of the Tellico-Sevier syncline mapped in the Vonore area contains rocks from Lower Cambrian Rome Formation through the lower Mississippian Grainger Formation (Fig. 2-1). The stratigraphic column for the southern Tellico-Sevier syncline needed to be mapped in sufficient detail to distinguish potential Quaternary paleoseimic features (many of which can be mimicked by stratigraphic features such as sinkholes, soft-sediment deformation, or facies changes), while attempting to employ the established stratigraphic framework. The stratigraphic sequence used herein in the Tellico-Sevier syncline (Fig. 2-2) generally conforms with the traditional Valley and Ridge stratigraphy in East Tennessee devised by Keith (1895) and Rodgers (1953) (Fig. 2-3), although neither stratigraphy satisfactorily described the Middle Ordovician Chickamauga Group rocks below the Bays Formation. Initially, Neuman's (1955) (Fig. 2-3) modification of these two stratigraphies was used in the study area (Fig. 2-4). Review of other work on the Chickamauga Group, however, revealed a hodgepodge of stratigraphic nomenclature. Facies changes are common in the Chickamauga, and many previous workers felt each mappable facies deserved a separate name. Unfortunately, previous workers observed facies changes both along and across strike, and were not consistent with naming rock units. Some workers used a single name for time-equivalent rocks with dissimilar lithologies, others applied local names to each new rock type, and still others used a combination of these names to define a stratigraphy. Although a stratigraphic revision was not originally part of this research, a review of past stratigraphies is necessary to justify the hierarchy used here.

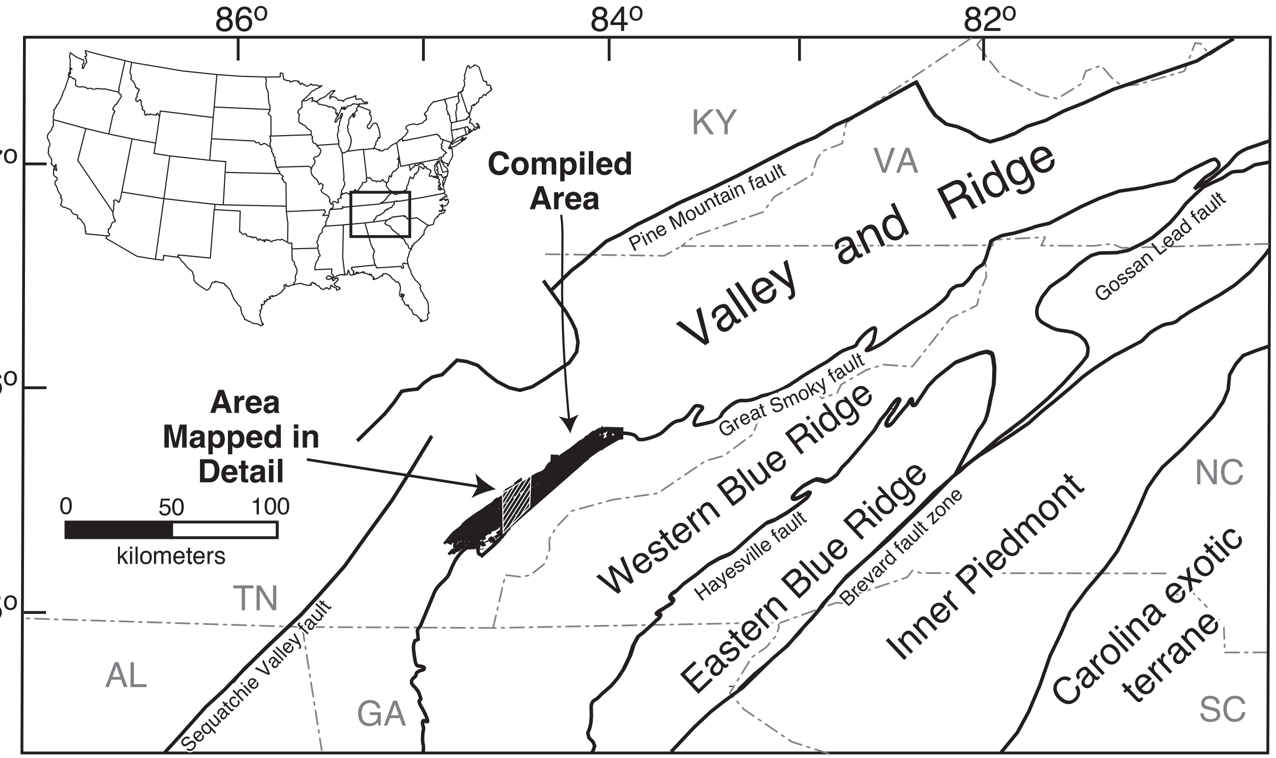


Figure 2-1. Simplified tectonic map of part of the southern Appalachians showing the location of the Valley and Ridge, the area of the compiled geologic map (black), and area mapped by the author (striped). Modified from Hatcher et al. (1990).

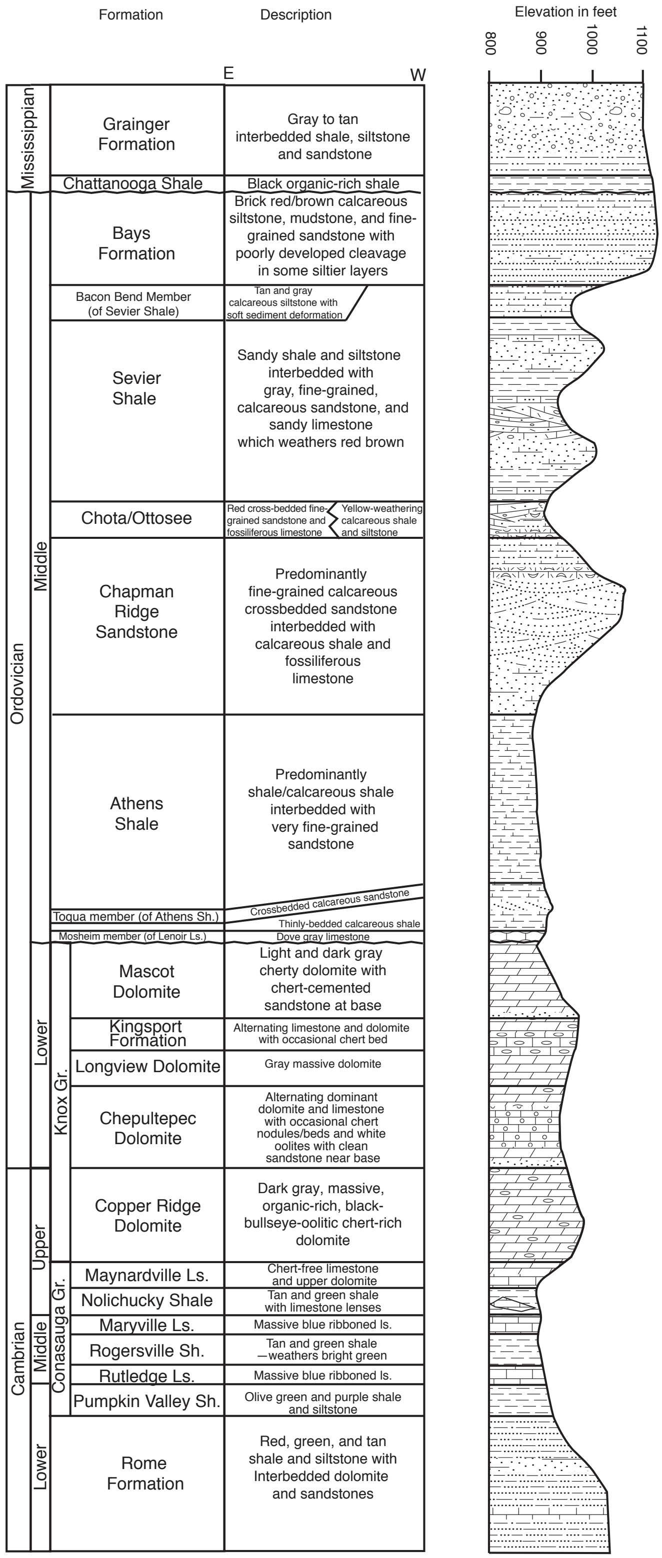
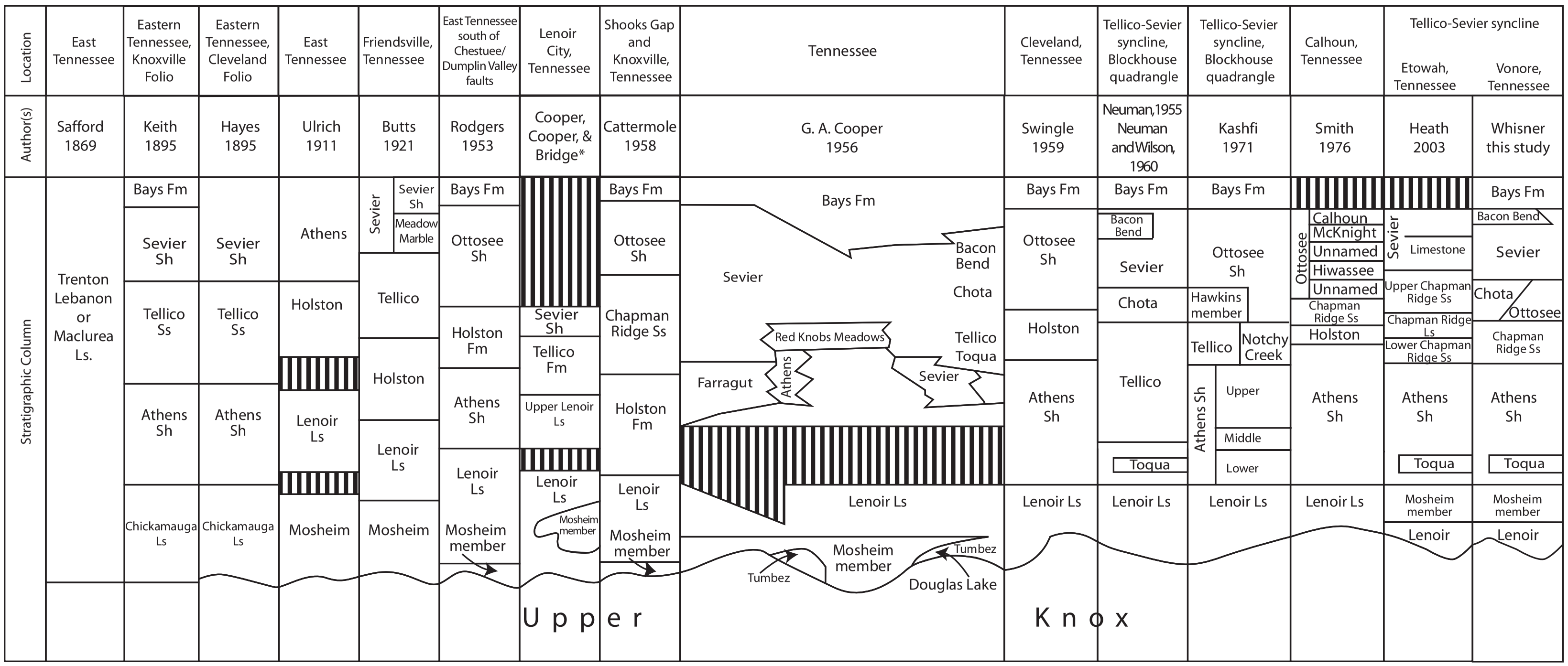


Figure 2-2. Generalized stratigraphic column of units in the field area. Righthand column shows rock type, relative resistance of units, and average elevations. (Modified from Neuman, 1955.)



*in Twenhofel et al. (1954)

Figure 2-3. Comparison of Middle Ordovician stratigraphy as it has been divided by various workers in southeastern Tennessee. Equivalent units are shown at the same level; stratigraphic thickness and timing are distorted. Lined areas were not recognized by the respective authors. Modified from McLaughlin (1973).

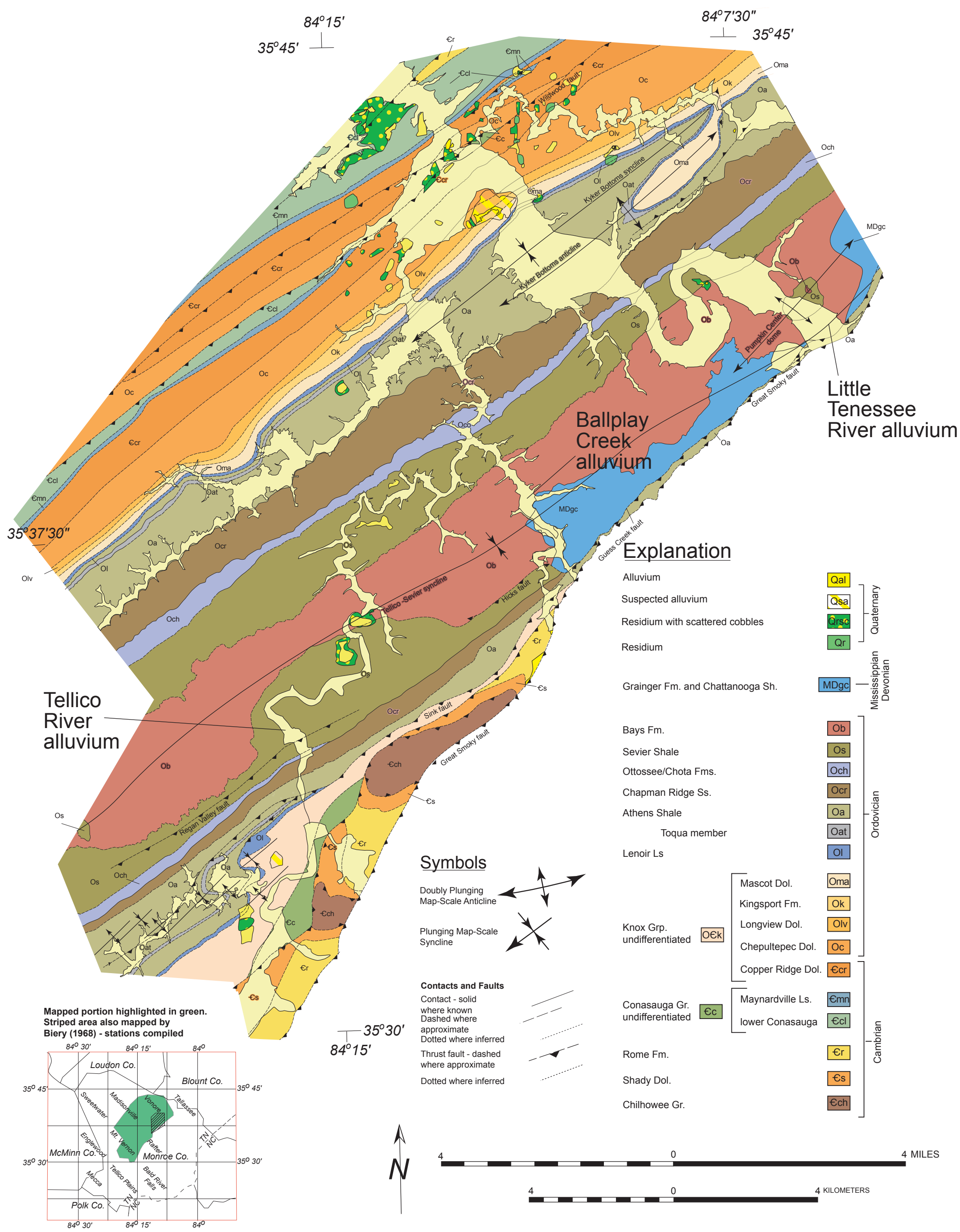


Figure 2-4. Generalized geologic map of the study area near Vonore, Tennessee.

Bedrock

Pre-Rome Formation units

Neoproterozoic Great Smoky Group and Lower Cambrian Chilhowee Group rocks occupy the hanging wall of the Great Smoky fault and its splays along most of the southeastern boundary of the mapped area. Colluvium and alluvium derived from these rocks were noted but not mapped in detail. The oldest unit mapped in the actual field area is the Lower Cambrian Rome Formation.

Rome Formation

The Lower Cambrian Rome Formation, named by Hayes (1891), can be divided into a lower member, the Apison, a variegated shale/siltstone unit present in the field area, and an upper sandstone-variegated shale-dolomite-bearing member (not seen). Two Rome outcrops occur here and consist of red and green thinly bedded shale and siltstone, one along the Tellico River and the other in the hanging wall of a minor thrust sheet along Ballplay Creek near Harlan Mountain (Fig. 2-5). The thickness of the Rome in the study area is indeterminate because no complete section exists, although it is generally assumed to be more than ~210 m (700 ft) thick (Rodgers, 1953, p. 45; Roeder et al., 1978). The contact between the Rome and the Conasauga was not mapped in the study area.

Conasauga Group

The Middle-Upper Cambrian Conasauga Group, named for outcrops along the Conasauga River in Whitfield and Murray Counties, Georgia (Hayes, 1891; Walcott, 1891), is approximately 600 m (~1970 ft) thick in East Tennessee (Rodgers, 1953; Swingle, 1959; Hatcher et al., 1992) and lies above the Rome Formation. The Conasauga here consists of six units, the lower four of which were not observed in the field area (Rodgers, 1952,1953; Swingle, 1959, Hasson and Haase, 1988). The lowest unit in the

Figure 2-5. Typical Rome Formation red shale along Antioch Church Road, Rafter 7.5-minute quadrangle. Rock hammer is 0.3 m (11 in) long.

Conasauga is the Pumpkin Valley Shale, an olive to purple shale and siltstone. This is overlain by the Rutledge Limestone, a light gray ribbony limestone, the Rogersville Shale, a tan to green shale which weathers a characteristic bright green (Rodgers, 1953), and the Maryville Limestone, a light gray limestone interbedded with calcareous shale and siltstone. The upper two units were observed in the field area. The Nolichucky Shale is an olive green and gray shale with interbedded discontinuous limestone units (Rodgers, 1952; Swingle, 1959; Hasson and Haase, 1988), and the top unit, the Maynardville Limestone (Oder, 1934; Rodgers, 1953; Swingle, 1959; Hasson and Haase, 1988) is a medium gray, medium bedded limestone and dolomite (45 m or ~150 ft thick) that is up to 120 m (400 ft) thick in other areas. The Maynardville is differentiated from the overlying Copper Ridge Dolomite of the Knox Group by a thin sandstone along the contact and a lack of chert; characteristic algal and oolitic cherts exist in the Copper Ridge.

The upper Conasauga occurs primarily in the northwest portion of the mapped area. The Maynardville Limestone outcrops at the northeastern boundary of the field area just to the south of U.S. 441 in the faulted portion of the northwestern limb of the Tellico-Sevier syncline. Nolichucky Shale occurs in a fault block straddling U.S. 441 near Vonore; it also outcrops at the base of the hanging wall of a fault following the trace of Fourmile Creek south-southwest of Vonore, Tennessee (Plate I). Conasauga shale can also be found in float in Ballplay Creek Valley northeast of Harlan Mountain.

Knox Group

Above the Conasauga lies the Cambrian-Ordovician Knox Group, named by Safford (1869) for outcrops in Knoxville, Tennessee. This unit, consisting of cherty limestone and dolostone, has five subdivisions (Butts, 1926; Oder and Miller, 1945; Rodgers, 1953; Lemiszki, 1992), four of which are readily distinguishable in the study area.

The lowermost Knox unit is the Upper Cambrian Copper Ridge Dolomite (Ulrich, 1911; Hardeman et al., 1966), which is approximately 300 m (1000 ft) thick. It contains organic-rich, dark gray, fetid, crystalline dolomite with algal chert, occasional vuggy limestones near the upper portions and abundant black, bullseye, oolitic chert (Fig. 2-6). The Copper Ridge underlies rolling ridge topography in the northwestern portion of the field area.

The Ordovician Chepultepec Dolomite (210 m or 700 ft) (Ulrich, 1911) overlies the Copper Ridge. The contact between the Chepultepec and the Copper Ridge is not generally exposed, but is marked by a 3 m- (10 ft)-thick, fine-grained, very clean dolomite-cemented sandstone (Figs. 2-7 and 2-8) at the base of the Chepultepec. This sandstone layer is exposed along the south side of Trigonia Road approximately 120 m (400 ft) east of a sharp dogleg away from Ninemile Branch in the southwest corner of Blount County. The sandstone holds up a low ridge in the northern portion of the mapped area near the Little Tennessee River, but is less easily recognized further south. The Chepultepec contains a mix of dark gray algal limestone (mostly at the base) and dolomite with some banded cherty zones and occasional white oolitic chert layers. It generally forms valleys in the field area because of the lesser amounts of chert present. Good outcrops are only found along Tellico Reservoir.

The Longview Dolomite (Fig. 2-9) and Kingsport Formation (together 150 m or 500 ft thick) are difficult to differentiate in the field and were generally mapped based on their contacts with the underlying Chepultepec or the overlying Mascot. The prominent ridge typical of the Longview in other parts of East Tennessee is not as prominent in the field area. The upper Longview is similar to the Kingsport. A predominance of limestone in outcrop indicates a change to Kingsport. The units tend to form low ridges (more typical of the Longview) with scattered sinkholes and stream valleys (more typical of the Kingsport).

Figure 2-6. Typical exposure of Cambrian Copper Ridge Dolomite along Tellico Reservoir at Fort Loudon State Park. Weathered dolostone is visible in the background. Hammer head is parallel to bedding. Hammer is 0.3 m (12 in) long.

Figure 2-7. Typical outcrop of dolomite-cemented quartz arenite in the lower Chepultepec along Trigonia Road south of Militia Springs. Pencil is oriented parallel to bedding that is near vertical to slightly overturned. Bed thickness is about 0.6 m (2 ft). Pencil is 0.16 m (6.5 in) long.

Figure 2-8. Surface of Ordovician Chepultepec Dolomite quartz arenite (same as Fig. 2-7). Individual sand grains can be seen. Pencil is 0.16 m (6.5 in) long oriented perpendicular to bedding.

Figure 2-9. Ordovician Longview Dolomite along Russell Hollow Road. Hammer head is 0.15 m (6 in) long.

The Mascot Dolomite is a gray to pink moderately cherty dolomite with reddish color (terra rosa) near the top in some locations. The Mascot is approximately 120 m (400 ft) thick at the top of the Knox Group, and was named after outcrops in Mascot, Tennessee by Oder and Miller (1945). The contact between it and the Longview/ Kingsport below can be identified by a 3 m (10 ft) thick sequence of interbedded dolomite and chert-cemented, mature sandstone. This sandstone was observed in only one outcrop near Kyker Bottoms in the northernmost portion of the mapped field area. The Mascot forms low ridges overlooking valleys of Athens Shale.

The top of the Knox Group is marked by a regional disconformity separating Lower and Middle Ordovician age rocks (Rodgers, 1953; Bridge, 1955). The disconformity may have topographic relief of up to 60 m (200 ft) (Rodgers and Kent, 1948) in East Tennessee and as much as 240 m (800 ft) in southwestern Virginia (B. N. Cooper in Bridge, 1955). The disconformity is marked by paleosol development (terra rosa), karst features, and collapse breccias (Rodgers, 1953; Walker, et al., 1992).

Chickamauga Group

The Chickamauga Group (Swingle, 1959), originally called the Chickamauga Limestone by Hayes (1894), consists of Middle Ordovician rock units ranging from limestone to shale and sandstone lying unconformably above the Cambro-Ordovician Knox Group carbonates. All units are calcareous to some degree. Contacts between most units in the Chickamauga are commonly gradational on varying scales.

Unraveling the stratigraphic sequence of the Chickamauga Group has continued for some time (Fig. 2-4). It was first described by Safford (1869), and refined by Keith (1895); Rodgers (1953); Neuman (1955); Cattermole (1958); Kashfi (1971); Leroux (1974); Smith (1976); Shanmugam (1978); Caldwell and Parker (1989); and others. Geologists working within the Chickamauga Group have recommended revisions to the stratigraphy and applied names to units in it as they saw fit or that matched lithologically similar units identified elsewhere in the Valley and Ridge. This has caused trouble when trying to correlate units with the same given name between distant locations both along and across strike. Local names cause additional confusion because they identify local facies changes that have been correlated with the more widely accepted and applied regional stratigraphy. The Chickamauga as described here takes the most applicable formation names from previous workers and applies them based on outcrop and hand sample characteristics. Lithologic variability within specific units is noted but not used as a basis for applying a new stratigraphic nomenclature to facies changes in regional units.

Lenoir Limestone

Lying disconformably above the Knox Group (Fig. 2-10) and conformably beneath the Athens shale is the Lenoir Limestone, named by Safford and Killebrew (1876). The Lenoir is a gray, micritic nodular limestone 15-30 m (50-100 ft) thick with occasional fossils and rip-up clasts of underlying Mascot at its base. It has a cobbly or rubble pile appearance when weathered on lower dip slopes of ridges held up by the Mascot. The Lenoir can be positively identified by the appearance of the gastropod *Maclurities magnus* (Fig. 2-11). The Mosheim Member (Ulrich, 1911) of the Lenoir is the predominant lithology outcropping in the field area. The Mosheim is a massively bedded, dove gray, micritic limestone. The contact between the Lenoir and the underlying Mascot Dolomite is rarely seen in outcrop. More often, the author would observe a change in rock type and realize he had crossed the contact.

Athens Shale

The Middle Ordovician Athens Shale, named by Hayes (1894) in the Kingston Folio for shales between the basal Middle Ordovician limestone “Chickamauga Limestone” and the Tellico Sandstone, in this area is a dark gray to tan and light olive green, thinly bedded, calcareous shale 120-180 m (400-600 ft) thick with occasional thin limestone and siltstone beds, commonly in the upper portion. Tan and green are

Figure 2-10. Ordovician unconformity between the Ordovician Mascot Dolomite and overlying Mosheim Member of the Lenoir Limestone at Nonaburg, TN (Etowah quadrangle). This outcrop is 1 m (3 ft) high. Rip-up clasts of Mascot Dolomite in the Mosheim are visible as lighter colored fragments along the contact.

Figure 2-11. *Maclurities magnus* gastropod in Mosheim limestone to left of pencil in the Nonaburg outcrop. Pencil is 0.16 m (6.5 in) long.

commonly the colors of weathered outcrop; but fresh surfaces are dark gray (Figs. 2-12 and 2-13). Graptolites can be found throughout the Athens, but few were seen in outcrop by the author. More calcareous layers form subdued ridges, but the majority of the unit underlies stream valleys. Neuman (1955) used the term “lower Tellico Formation” for the calcareous shale-dominated rocks between the Lenoir Limestone and the Chota limestones and sandstones, but the more commonly used term “Athens” of Rodgers’ (1953) geologic map is used here. Shale is replaced near the base of the Athens by the Toqua Sandstone Member (Neuman, 1955), a 30-45 m (100-150 ft) thick, brown, fine- to coarse-grained, medium-thick bedded, cross-bedded, calcareous sandstone, throughout the field area (Fig. 2-14). The Toqua is poorly exposed in most of the field area, and found mostly as float or as a low ridge within the Athens Shale. Better outcrop exists to the south in the hinge of the syncline mapped by Heath (2003). The Toqua, while relatively continuous, appears to change position in the Athens, moving up section 15m (50 ft) along strike to the southwest. Grain size and bed thickness in the Athens gradually increases up section until the rock is mostly sandstone near its conformable contact with the overlying Chapman Ridge Sandstone.

Chapman Ridge Sandstone

The rocks called “Chapman Ridge Sandstone” in the study area were originally called “Tellico Sandstone” by Keith (1896) in the Loudon folio, who used the term for red-weathering calcareous sandstone that separates Athens Shale (below) from the Sevier Shale (above) in the Loudon folio. “Tellico Sandstone” was also used by Neuman (1955) in the study area, and the same units were called the Notchy Creek facies of the Tellico Formation by Kashfi (1971). The name Chapman Ridge was originally suggested by Cattermole (1955) in the Shooks Gap 7.5-minute quadrangle for red, calcareous sandstone interbedded with shale and silty shale between the lower tongue of the Ottosee Shale or, where the contact is missing, the Holston Marble and the main body of the

Figure 2-12. Tan (weathered) and gray (fresh) Athens calcareous shale along Tennessee Highway 72 near Smoky Branch boat landing. Fissility can be seen clearly. Pencil oriented subparallel to strike, pointing down dip, is 0.16 m (6.5 in) long.

Figure 2-13. Tan weathered Athens calcareous shale along Tennessee Highway 72 near Smoky Branch boat landing. Pencil cleavage is produced by intersection of weak cleavage and bedding. Pencil is 0.16 m (6.5 in) long.

Figure 2-14. Toqua Member tan fine-grained sandstone south of Hamontree Branch east of Tennessee Highway 72. Pencil is 0.16 m (6.5 in) long.

Ottosee above. Cattermole defined the Chapman Ridge Sandstone in the mistaken belief (Walker et al., 1983) that the Chapman Ridge exposed in Knoxville is much younger than the lithologically similar Tellico Sandstone of Keith (1895) in its type locality along the Tellico River. Cooper (1956) also considered the Tellico Sandstone to be older than Chapman Ridge. On Rodgers' (1953) geologic map of East Tennessee (and later on the Tennessee state geologic map [Hardeman et al., 1966]), both the Tellico Sandstone and Chapman Ridge units were mapped within the Holston Formation in some thrust belts, and in the Athens Shale in others. Because the name Holston is also used in a more specific sense (i.e., Cattermole, 1958; Benedict and Walker, 1978; Walker et al., 1983) to refer to the predominantly reef facies calcarenite portions of Rodgers' (1953) and Hardeman et al. (1966) Holston Formation, confusion has arisen regarding the use of these names. The lithologic variability of Rodgers' Holston Formation across strike also causes confusion. In the standard belt (between the Saltville and Knoxville faults (Fig. 2-15), where the Holston and Chapman Ridge type sections are located, the Holston varies from coarsely crystalline shell hash limestone ("lime sandstone"), to reef and reef debris zone limestones, and a frequently overlying more quartzose "lime sandstone". The weathering profile of the quartz-rich facies suggests it is distinct from the regular lime sandstone, although Rodgers (1953) described them as interbedded. In the middle belt, between the Knoxville and Chestuee/Dumplin Valley faults (Fig. 2-15), quartz abundance increases southward, especially in the lower parts of the formation, and in fact Rodgers (1953) called the Tellico Sandstone (Chapman Ridge of Cattermole 1955, 1958) "merely a quartzose phase of the Holston" in these two thrust belts. On the other hand, in the thrust belt east of the Chestuee and Dumplin Valley faults, Rodgers (1953) placed the Tellico Sandstone not in the Holston Formation, but in the upper Athens Shale, rather than using it to separate Athens from Sevier, as Keith (1895) did, and stated that, in his estimation, none of the sandstones in the easternmost belt can be correlated with

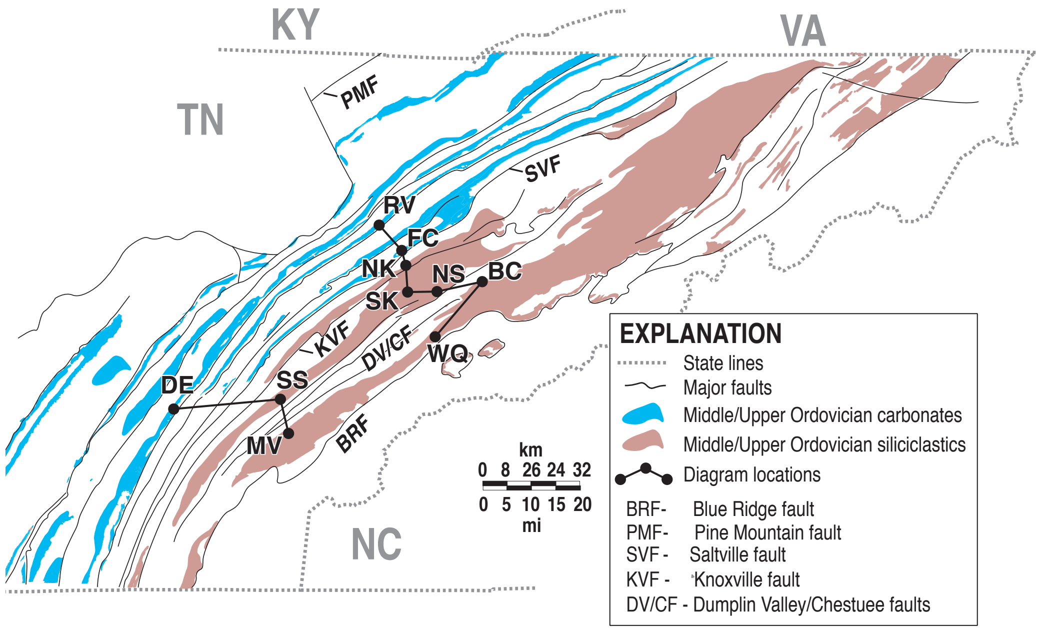


Figure 2-15. Regional extent of the Middle Ordovician Chickamauga Group. Major faults referred to by Rodgers (1953) are shown. Locations of basin cross sections from Walker et al. (1983) are also plotted. Northern cross section is between Raccoon Valley (RV) and the Wildwood 7.5-minute quadrangle (WQ). Southern cross section is between Decatur (DE) and Mount Vernon (MV). Other quadrangles referenced are Boyds Creek (BC), Fountain City (FC), North Knoxville (NK), Neubert Springs (NS), South Knoxville (SK), and Sweetwater (SS). Lines DE-MV and RV-WQ are shown in Figure 2-18.

the Holston Formation as mapped in the standard belt. Kashfi (1971) proposed that the Chapman Ridge/Tellico Sandstone/Notchy Creek facies of the Tellico/Chota were all part of a recurring deltaic sequence that drowned the Holston reefs. I believe Kashfi's depositional interpretation of this system is correct and feel that the contacts should be drawn based on the primary lithology of the unit allowing for what are ultimately minor facies changes.

The Chapman Ridge Sandstone (Ferrigno, 1973; McWilliams, 1975; Smith, 1976) in the area of detailed mapping consists of grey (fresh surface) to red to reddish brown (weathered surface) interbedded, cross-bedded, calcareous sandstone (Fig. 2-16) and fossiliferous limestone with occasional shale and is approximately 460 m (1500 ft) thick, although its thickness varies across and along its depositional belts, as discussed further in Chapter 3. Scattered trace fossils (burrows) are found in many locations. The Chapman Ridge Sandstone forms prominent ridges (e.g., Notchy Creek Knobs, Red Knobs, Red Mountain) that outline the syncline. The contact with the Athens is gradational in most places and is seldom exposed.

McWilliams (1975) saw the Chapman Ridge immediately above Holston-type rocks in the Athens syncline to the northwest, but in my field area and in other locations across and along its depositional belts, the Chapman Ridge occurs in combination with or replacing Holston-type "marbles" and cross-bedded fossiliferous limestones. Holston is a catchall term used to describe units associated with reefal crystalline limestones regardless of stratigraphic position, so I have referred to such limestones as Holston-type, to avoid further confusion.

Chota/Ottosee Formation

The Chota and Ottosee occupy the same stratigraphic level (between Chapman Ridge Sandstone and Sevier Shale), but are neither proper lithostratigraphic units (because identification is based on stratigraphic position, rather than the variable

Figure 2-16. Cross-bedded Chapman Ridge Sandstone along Tellico Reservoir near Bacon Bend wildlife refuge. Hammer is 0.3 m (12 in) long.

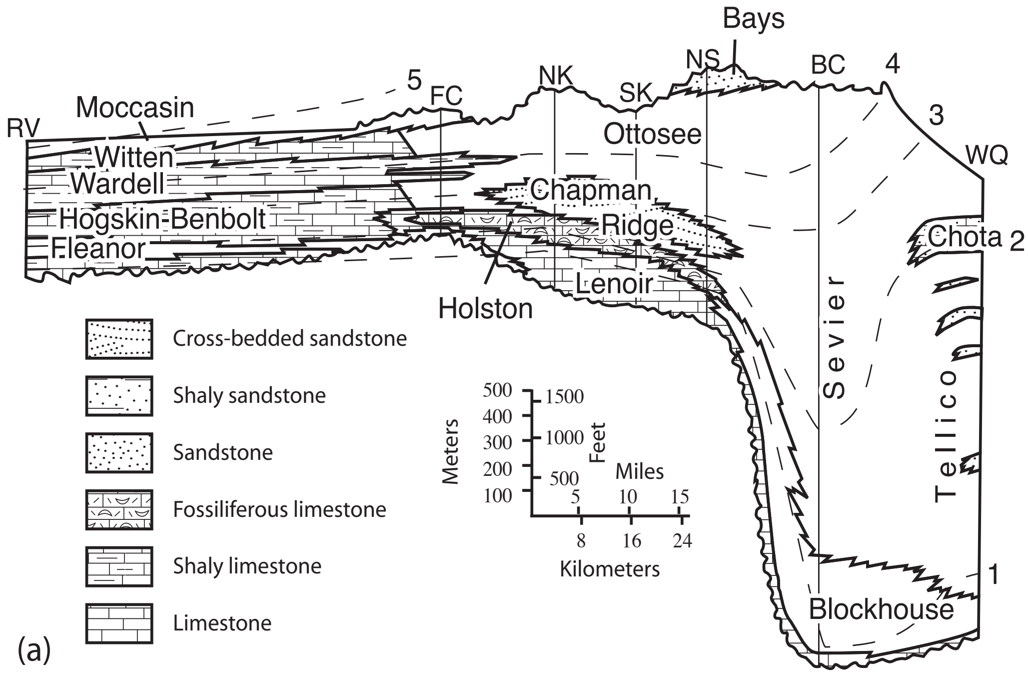
lithologic characteristics) nor chronostratigraphic units (because they are time-transgressive to the southwest). The Chota, named by Neuman (1955) for rocks near the former site of the Chota school along the Little Tennessee River in Monroe County, consists of approximately 92 m (300 ft) of medium-grained, red-tinted gray (fresh surface) to red-reddish brown (weathered surface), cross-bedded sandstone interbedded with calcareous shale and brachiopod- and bryozoan-rich fossiliferous limestone (Fig. 2-17). The cross-bedded sandstone portion of the Chota is very similar to the sandstones in the Chapman Ridge Sandstone (Fig. 2-18). The sandstones of the Chota (called the Hawkins Member of the Ottosee by Kashfi [1971], and the "sandstone lentil" of the Sevier by Keith [1895]) pinch out southwest of the Tellico River (Fig. 2-19), leaving only a band of discontinuous reefal limestone, calcareous siltstone, and shale (Fig. 2-20). The Chota is not recognized as a mappable unit on the southeastern limb of the syncline (Plate II).

Swingle (1959) and Kashfi (1971) applied the term "Ottosee" as it was used by B. N. Cooper, G. A. Cooper, and J. M. Cattermole (in Neuman, 1955) in the Friendsville-Knoxville belt of Middle Ordovician rocks, and Rodgers (1953) in the Dumplin Valley and Chestuee thrust sheet, to calcareous shale and limestone units between the Holston Formation/Chapman Ridge Sandstone and the Bays Formation. In this study, "Ottosee Formation" has been used in a more restrictive sense (Thigpen, 2002), to apply to the fossiliferous limestone, siltstone (Fig. 2-21), and shale that lie in the same stratigraphic position as Neuman's "Chota Formation," where the Chota Formation sandstone is absent because of facies changes, primarily in the southern end of the Tellico-Sevier syncline (Plate II). I suspect, based on the similarities with the Chapman Ridge (cross bedding, grain size, and hematite concentration) that the Chota may be the "last gasp" of the Chapman Ridge before the appearance of more shaly and limey units of the Sevier Shale, but with interruptions in sandstone deposition long enough for the reef limestones to

Figure 2-17. Bryozoan-, brachiopod-, and crinoid-rich limestone of the Chota/Ottosee Formation along the south side of Three Point Road 610 m (200 ft) east of Soak Road. Pencil is 0.16 m (6.5 in) along.

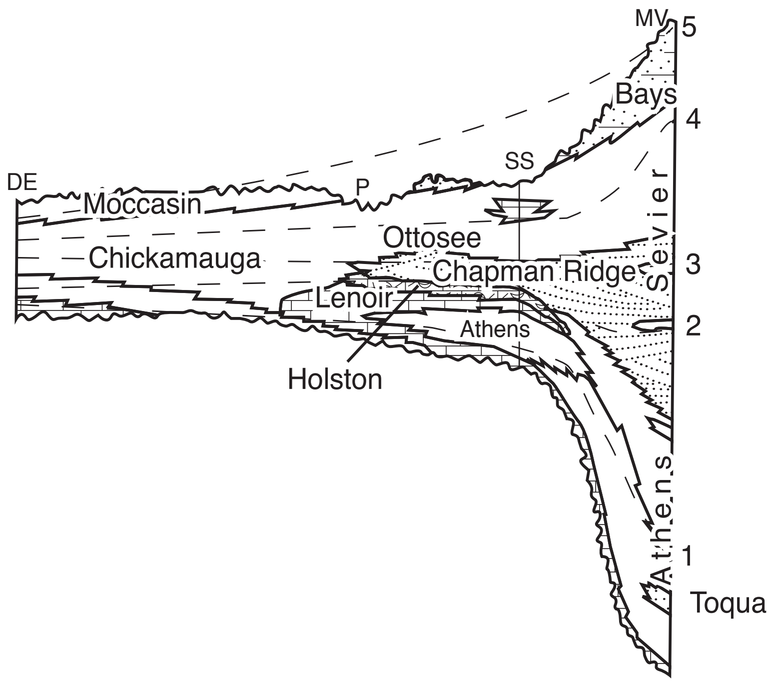
Figure 2-18. Cross-bedded hematite-rich sandstone. Outcrop of “Chota” along the type-section of Neuman (1955) near where Chota School originally stood. Pencil is 0.16 m (6.5 in) long.

Figure 2-19. Schematic Middle Ordovician Tellico-Sevier basin diagrams of Walker et al. (1983). (a) Facies relationships from Raccoon Valley (RV) to Fountain City (FC) through Knoxville (NK and SK) and continuing to Neubert Springs (NS) and Boyds Creek (BC) ending in the Wildwood 7.5-minute quadrangle (WQ). (b) Decataur (DE) through Sweetwater (SS) ending in Mount Vernon (MV). Time lines 1 through 5 (dashed) show time equivalent horizons through both diagrams. Time line 2 traverses the lower third of the Chapman Ridge in the Mount Vernon quadrangle and through the Chota in the Blockhouse quadrangle, indicating the Chota is time transgressive. Units without patterns are predominantly shale. Chota limestone (at Time 2) is separated from thinner sandstone units below in the Wildwood quadrangle grading to Ottosee (not differentiated from lower Sevier) shale and fossiliferous limestone above the Chapman Ridge Sandstone (at Time 3) in the Mount Vernon quadrangle to the south.



Bays
NS
BC
4
5
FC
NK
SK
RV
Moccasin
Ottosee
3
WQ
Witten
Wardell
Chapman
Hogskin-Benbolt
Ridge
Chota
2
Fleanor
Lenoir
Holston
Sevier
Tellico
Cross-bedded sandstone
Shaly sandstone
Sandstone
Fossiliferous limestone
Shaly limestone
Limestone
Meters
Feet
Miles
Kilometers
1
Blockhouse

(a)



MV
5
Bays
4
SS
DE
Moccasin
P
Sevier
Ottosee
Chickamauga
Chapman Ridge
3
Lenoir
2
Athens
Holston
Athens
1
Toqua

(b)

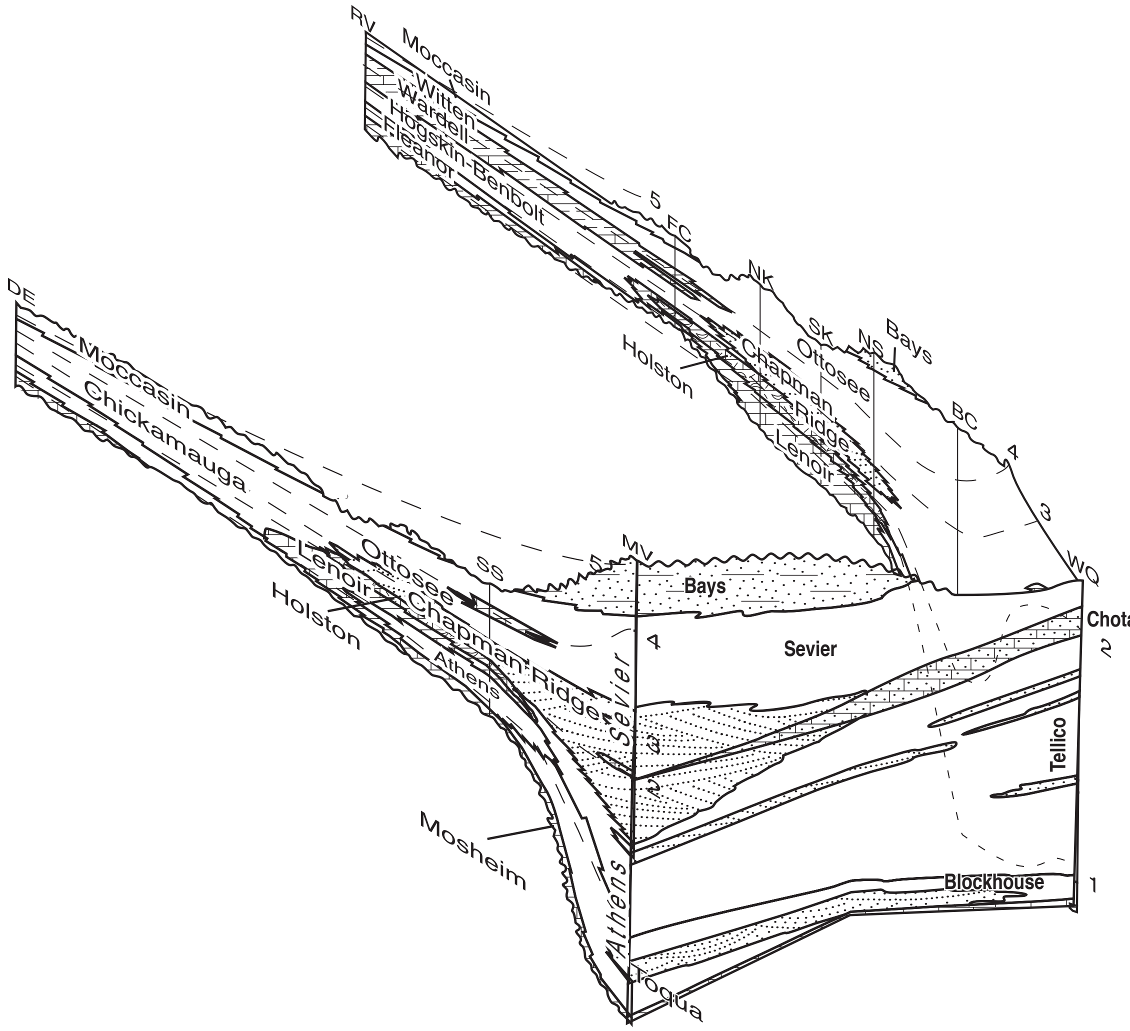


Figure 2-20. Chickamauga facies changes along strike between Wildwood (WQ) and Mount Vernon (MV) 7.5-minute quadrangles. Modified from Walker et al. (1983).

Figure 2-21. Ottosee siltstone on the north side of Three Points Road 610 m (2000 ft) east of Soak Road. Hammer head is 0.15 m (6 in) long.

form continuous units. Not only does the Chota's lithology change along strike, but also its timing of deposition. Based on conodont biostratigraphy and sequence stratigraphy, Benedict and Walker (1978) interpreted the Chota in the Wildwood 7.5-minute quadrangle (northeast of the study area) as a time equivalent of the lower Chapman Ridge in the Mount Vernon 7.5-minute quadrangle in the study area. This implies the Chota must be time transgressive along strike, younging to the southwest (Fig. 2-19). This may be because both the depositional environment and the location of the depocenter changed through time, from a carbonate-rich environment in the northern portion of the compiled area to more clastic rich as the depocenter moved southwest toward the southern end of the compiled area (Plate II).

Sevier Shale

Lying conformably above the Chota/Ottosee is the Sevier Shale, a 550 m (1800 ft) thick sequence of calcareous sandstone, calcareous siltstone, calcareous shale, and limestone. The Sevier Shale was named by Keith (1895) for a wide belt of shale in Sevier County. The term Sevier Shale, as used here, is closest to Neuman's (1955) restricted usage, rather than Keith's (1895) and Rodgers' (1953) broad use of the name for all units between the Knox Group and Bays Formation. The Sevier changes character to include more sandy, silty limestone as well as clean micritic limestones interbedded with shale in the central and southern portions of the Tellico-Sevier syncline. Grain size gradually increases higher in the stratigraphic section, making the lower portion of the Sevier more shaly and the upper portion more sandy. Differential erosion of this unit creates a mixed topography of discontinuous ridges and valleys. The many fossiliferous limestone beds of bryozoan, crinoid, and brachiopod shell hash in the Sevier are similar to those in the Chota/Ottosee but are not restricted to a narrow band as they are in the lower unit. The contact between the Sevier and Bays Formation is marked by the Bacon Bend Member (Neuman, 1955) of the Sevier, a 10-43 m (35-140 ft) thick siltstone with pervasive soft-sediment deformation and shell hash (Fig. 2-22), postulated to be caused by large storms. This unit is easily distinguishable in the field area near Bacon Bend on the Little Tennessee River where it was described by Neuman (1955), but becomes more difficult to identify in the field as the Bays/Sevier contact is mapped further south and may disappear altogether. It was not mapped by Kashfi (1971), Thigpen (2002), or Heath (2003).

Bays Formation

The upper Middle Ordovician Bays Formation (Campbell, 1894) is a 305 m- (1000 ft-) thick brick red and purple, calcareous, medium-grained mudstone, siltstone and sandstone and with siltstone and mudstone near the base and grain size increasing up section (Fig. 2-23). In the field area it is only about 100 m (350 ft) thick. It is occasionally cross bedded in the sandier units and silty beds display well-developed cleavage. It is the youngest remaining Ordovician unit in the field area and its upper portions have been removed by erosion. It forms high ridges in the core of the syncline. Good outcrop exists from TN State Hwy 68 to the Little Tennessee River near Pumpkin Center.

Chattanooga Shale

The Devonian-Mississippian Chattanooga Shale (Hayes, 1894) lies unconformably above the Bays, a 12 m (50 ft) thick organic-rich black shale that weathers tan (Fig. 2-24). The Chattanooga Shale is easily found in outcrops near the Little Tennessee River along Citico Road within ridges capped by the Mississippian Grainger Formation but is normally covered on wooded slopes by colluvium from the Grainger.

Grainger Formation

The exposed thickness of lower Mississippian Grainger Formation (Rodgers, 1953) is 335 m (1100 ft), and is a combination of tan sandstone and shale, and contains

Figure 2-22. Map view of bedding of Bacon Bend Member of the Sevier Shale along Highway 72 near Pumpkin Center. Hammer head (0.15 m or 6 in) is near a mud ball and folded bedding that is interpreted as soft-sediment deformation (Neuman, 1955).

Figure 2-23. Brick red calcareous siltstone of the Middle Ordovician Bays Formation along Sloan Road on west bank of Tellico River. Bedding is horizontal parallel to head. Cleavage is vertical. Hammer is 0.3 m (12 in) long.

Figure 2-24. Highly jointed, weathered Devonian-Mississippian Chattanooga Shale. Swingle (1959) called weathered Chattanooga coffee colored. Hammer is 0.3 m (12 in) long.

both marine and plant fossils. The Grainger is the youngest lithified unit in the study area (Fig. 2-25). The Grainger occurs as a high ridge along the southeast boundary of the study area, just northwest of the Guess Creek fault between the Little Tennessee River and Ballplay Creek, which marks its southernmost extent.

Quaternary Units

Quaternary colluvium and alluvium lie above the Paleozoic rocks. Identifying alluvium, both ancient and modern, is important because these deposits are most susceptible to deformation produced by earthquakes (could potentially record earthquakes with M>5 [required to produce a bedrock surface rupture]). Alluvium was identified early in the study to find old river terraces of the Little Tennessee and Tellico Rivers. In the present humid climate of East Tennessee, however, ancient alluvium (in the form of terrace deposits) can be difficult to distinguish from residuum, which may also contain cobbles of incompletely weathered bedrock. In addition, not all alluvium is equally useful in a search for paleoseismic evidence. For instance, alluvium from high flow, high volume streams would potentially be more widespread (permitting correlation of earthquake events from terrace to terrace) and be more likely to contain sediments that could produce liquefaction features when shaken. In addition, alluvium layers that are very thin are unlikely to preserve paleoseismic features that might once have been present. Thicker alluvial sediments also have a greater chance of containing age-datable material that could have been used to date any paleoseimic evidence. Terrace deposits were likely deposited from the Pleistocene to present.

To help distinguish alluvium from incompletely weathered residuum and identify those terraces/terrace levels most worthy of additional study, non-colluvial unconsolidated deposits were subdivided into three classes based on the presence, concentration and weathering characteristics of pebbles. The classes of unconsolidated deposits are residuum, residuum with scattered cobbles (suspect terrace deposits), and

Figure 2-25. Mississippian Grainger shale in typical outcrop in road above Chota/Tanasi Monument. Hammer is 0.3 m (12 in) long.

terrace deposits.

Residuum is untransported soil formed during weathering of various formations and may contain remnant structures inherited from the rock, angular to subrounded rock fragments, and other insoluble minerals. Soil color provides clues to parent material: tan soils indicate shale, while carbonates generally produce more reddish-orange soils. Knox Group carbonate residuum is more easily subdivided by the characteristic chert fragments developed on each unit. The sandstones of the Chapman Ridge Sandstone, Sevier Shale, and Bays Formation produce dark red to almost brown soil with varying amounts of sand. While residuum was generally of little use in the search for paleoseismic evidence because of the equivocal origin of the structures present, it was useful for mapping bedrock contacts where solid rock outcrops do not exist.

Residuum containing scattered cobbles is similar to residuum but contains rounded cobbles of vein quartz, graywacke, and other rock types derived from units in the Blue Ridge as well as units in the field area. These rounded cobbles (especially vein quartz) suggest an alluvial source for the deposits. A large stream or river would be needed to transport vein quartz, which is not found in large enough quantities to form cobbles in the Valley and Ridge, from the Blue Ridge in the hanging wall of the Great Smoky fault. Deposits were mapped as residuum with scattered cobbles if there were fewer than 10 cobbles or pebbles per square meter. This very subjective standard was established by Dr. Hugh Mills and the author to identify deposits that had potential for being river terrace deposits but were too weathered or of dubious origin (i.e., colluvium from higher terraces, deposits modified by people) to call terraces. Most deposits classified as residuum with scattered cobbles are likely eroded terraces where too little material is left to be of use in this study; their presence, however, suggests that better preserved terrace deposits could be identified at locations with similar elevations/bedrock type/topographic expression.

Terrace deposits were recognized as having more than 10 cobbles of vein quartz per square meter (Figs. 2-26). These deposits were then further examined to determine the degree of weathering of the quartz cobbles, size sorting of cobbles, cobble roundness, soil color, and deposit elevation. Degree of weathering was measured by breaking open cobbles and measuring the weathering rind and judging the cohesiveness of the cobbles. Degree of freshness was recorded on a scale of one to five with one being completely solid and five crumbling easily in hand. These two characteristics are an indication of the amount of time the cobble has been exposed to chemical and physical weathering. Sorting and roundness provide some indication of distance traveled from source area. Soil color was used initially as an indication of the age of a deposit but is not unique to terrace deposits; it is affected by underlying rock type in non-terrace deposits and so is less helpful than cobble weathering amount for age determination.

These characteristics were used to make a relative age determination between various deposits if paleoseismic evidence was found. A majority of cobbles of approximately the same size needed to have similar characteristics to permit an age estimate. Older deposits tend to occur at higher elevations and contain rounded cobbles that are more deeply weathered and less cohesive.

Locations of deposits along the Tellico River, Little Tennessee River, and other major streams are shown in the geologic map (Plate I). Quaternary deposits are broken up into the three broad classes described above as well as modern flood plain deposits. Flood plain deposits are located near streams no more than about 3 m (10 ft) above their modern elevation. Residuum exists across the map at all elevations wherever rock has weathered. Residuum with scattered cobbles was most often found between 250-275 m (820 -900 ft) near modern drainages on rolling Knox hills, but occasionally on other units. Knox weathering characteristics tend to produce the look of old dissected floodplains, flat to gently rolling with comparatively little outcrop. Older terrace deposits

Figure 2-26. Low terrace deposit above Knox along Russell Hollow Road. Hammer is 0.3 m (12 in) long.

occur at nearly any elevation; residuum with scattered cobbles could be found, most being relatively close to modern drainages and surrounded by a halo of residuum with scattered cobbles that are probably derived from the uphill terraces. A correlation exists between the height of old terrace deposits and the size of nearby streams, with the Little Tennessee and Tellico Rivers having a number of terrace deposits at or above 275 m (900 ft) elevation, 25 m (80 ft) above the present floodplain; whereas the smaller streams (Ballplay, Notchy, and Nine Mile Creeks) do not have high terrace deposits nearby.

CHAPTER 3

ROLE OF CHAPMAN RIDGE SANDSTONE IN SEVIER BASIN EVOLUTION

Introduction

The Chapman Ridge Sandstone is part of the Middle Ordovician Chickamauga Group. At its type section in Knoxville, Tennessee, the Chapman Ridge is a cross-bedded, hematite-rich, fine- to medium-grained, calcareous, quartz sandstone (Fig. 3-1) containing interbedded yellow shale overlying and intertonguing with massive Holston fossiliferous limestone (Cattermole, 1955). It has been interpreted as the product of an influx of coarse sediment into an evolving foredeep basin during the Middle-Late Ordovician Taconic orogeny (Rodgers, 1953; Kashfi, 1971; Shanmugam, 1978; Walker et al., 1983). It outcrops throughout much of the eastern Valley and Ridge of Tennessee from near Cisco, south of the Tennessee-Georgia border northward to Richland, Tennessee, just northeast of Knoxville (Fig. 3-2). It weathers to punky, low-density, dark brick-red saprolite that often retains the cross bedding and other physical characteristics of the unweathered outcrop (Fig. 3-3). Sand grains in the Chapman Ridge are relatively mature, fine grained, sub-angular to well rounded (fine grained sands tend to have a wider variety of angularities compared to coarser grained sand of the same maturity level) and well sorted.

This study was undertaken to address several questions related to the nature of the Chapman Ridge Sandstone and its role in the origin of the Sevier basin. These include: What is the source of this relatively mature sandstone? What does the cross bedding indicate about source area? What is the source of the iron and the conditions that formed the hematite? What does this unit tell us about the nature of the Blount-Sevier basin at the time of Chapman Ridge deposition?

Figure 3-1. Cross-bedded hematite-rich Chapman Ridge Sandstone in hinge of Tellico-Sevier syncline northeast of Etowah, Tennessee. Width of tree on right is 7.5 cm (3 in). Photo from Heath (2003).

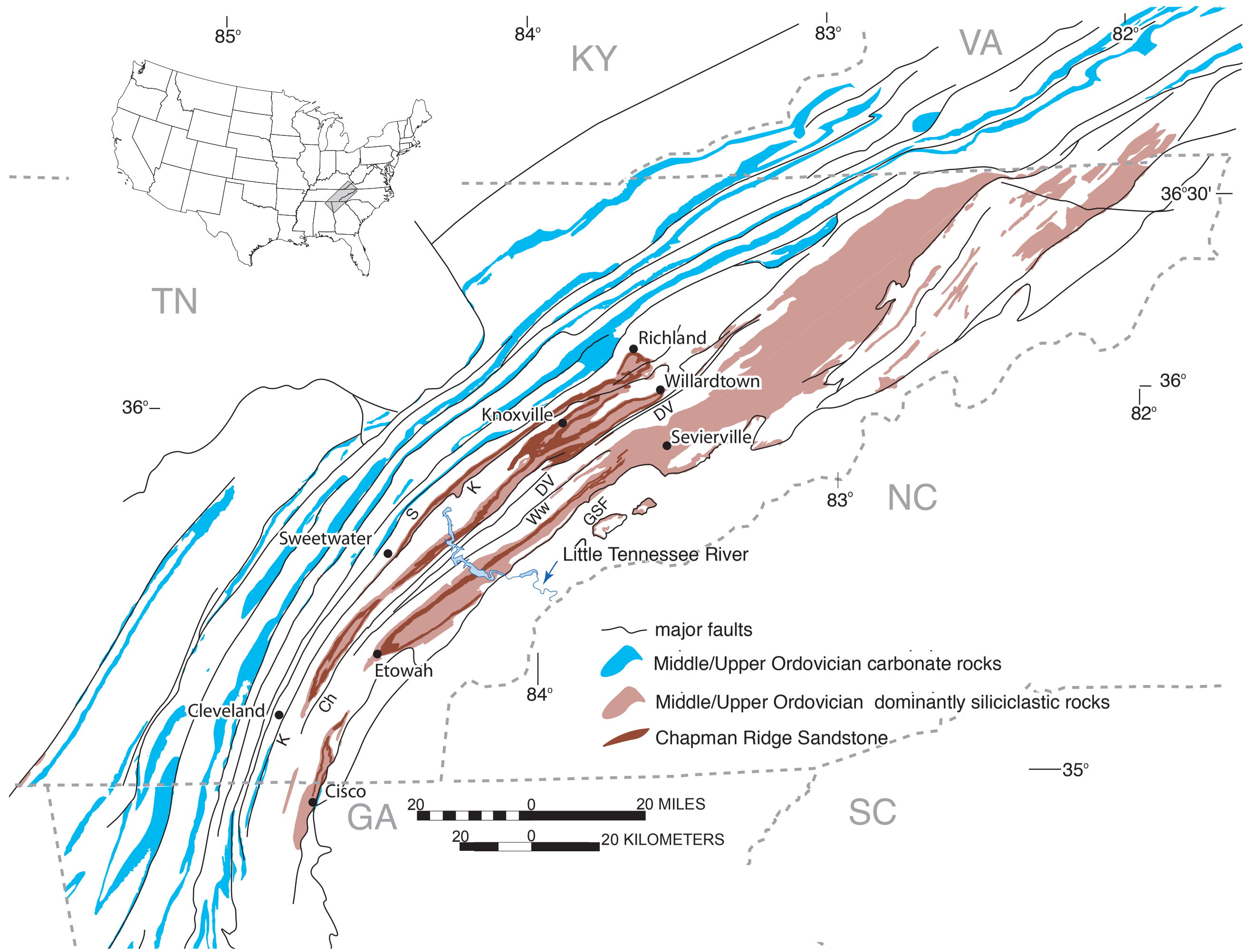


Figure 3-2. Extent of Chapman Ridge Sandstone outcrop (brick red) across East Tennessee and northwest Georgia. Three belts exist (from west to east) in the Saltville thrust sheet, the Knoxville thrust sheet, and the Chestuee/Dumplin Valley thrust sheet. Blue denotes more carbonate-rich shelf-type deposits. S = Saltville fault, K = Knoxville fault, Ch= Chestuee fault, DV = Dumplin Valley fault, Ww = Wildwood fault GSF= Great Smoky Fault.

Figure 3-3. Partially weathered cross-bedded, hematite-rich Chapman Ridge Sandstone along Tellico Reservoir near Bacon Bend. Hammer head rests on a cross bed. Hammer is 30 cm (12 in) long.

History of Chapman Ridge Research

The Chapman Ridge sandstone has not been recognized as a separate unit by many workers in East Tennessee. It has been mapped and grouped with the Holston Limestone, Athens Shale, Ottosee Shale, and Sevier Shale as well as given local names. The rocks called "Chapman Ridge Sandstone" in this study were originally called "Tellico Sandstone" by Keith (1896), who used the term for red-weathering calcareous sandstone that separates Athens Shale (below) from the Sevier Shale (above) in the Loudon folio. "Tellico Sandstone" was also used by Neuman (1955) in the Blockhouse quadrangle, and the same units were called the Notchy Creek facies of the Tellico Formation by Kashfi (1971) near Tellico Plains, Tennessee.

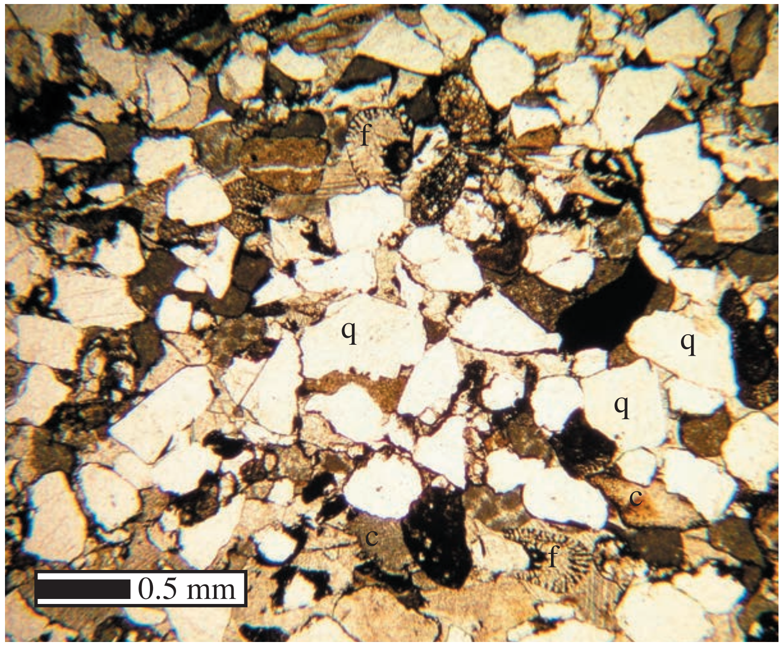
The name Chapman Ridge was originally suggested by Cattermole (1955) in the Shooks Gap 7.5-minute quadrangle for red, calcareous sandstone interbedded with shale and silty shale between the Holston Marble and the lower tongue of the Ottosee Shale or, where the lower tongue is not present, the main body of the Ottosee above. Cattermole defined the Chapman Ridge Sandstone in the mistaken belief (Walker et al., 1983) that the Chapman Ridge exposed in Knoxville is much younger than the lithologically similar Tellico Sandstone of Keith (1895) in its type locality along the Tellico River. Cooper (1956) also considered the Tellico Sandstone to be older than Chapman Ridge. On Rodgers' (1953) geologic map of East Tennessee (and later on the Tennessee state geologic map [Hardeman et al.,1966]), both the Tellico Sandstone and Chapman Ridge were mapped with the Holston Formation in some thrust belts and the Athens Shale in others. Because the name Holston is also used in a more specific sense (i.e., Cattermole, 1958; Benedict and Walker, 1978; Walker et al., 1983) to refer to the predominantly reef facies calcarenite portions of the Holston Formation of Rodgers (1953) and Hardeman et al. (1966), confusion has arisen regarding the usage of all of these names for the Chapman Ridge. The lithologic variability of Rodgers' Holston Formation across strike also causes confusion. In the standard belt of Rodgers (1953) between the Saltville and Knoxville faults (Fig. 3-1) the Holston varies from coarsely crystalline shell hash limestone ("lime sandstone") to reef and reef debris limestones interspersed with more quartzose "lime sandstone." The weathering profile of the quartz-rich facies suggests it is distinct from the regular lime sandstone, although Rodgers (1953) described them as interbedded. In the middle belt between the Knoxville and Chestuee/Dumplin Valley faults (Fig. 3-1) where the Holston and Chapman Ridge type sections are located, quartz abundance increases southward, especially in the lower parts of the formation; and in fact, Rodgers (1953) called the Tellico Sandstone (Chapman Ridge of Cattermole 1955, 1958) "merely a quartzose phase of the Holston" in these two thrust belts. On the other hand, in the thrust belt east of the Chestuee and Dumplin Valley faults, Rodgers (1953) placed the Tellico Sandstone not in the Holston Formation but in the upper Athens Shale, rather than using it to subdivide Athens from Sevier as Keith (1895) did and stated that, in his estimation, none of the sandstones in the easternmost belt can be correlated with the Holston Formation as mapped in the standard belt. Neuman's (1955) mapping and biostratigraphic work along the eastern margin of the Valley and Ridge caused him to subdivide the Athens Shale and the overlying Holston Formation; he named coarse-grained, cross-bedded hematite stained sandstones with interbedded shale he called the Tellico Sandstone and where it was mixed with massive reefal limestone, he called it the Chota. Mapping south of Neuman, Kashfi (1971) concluded the Chapman Ridge/ Tellico Sandstone/Notchy Creek facies of the Tellico/Chota are part of a recurring deltaic sequence that drowned the Holston reefs.

Mapped Extent

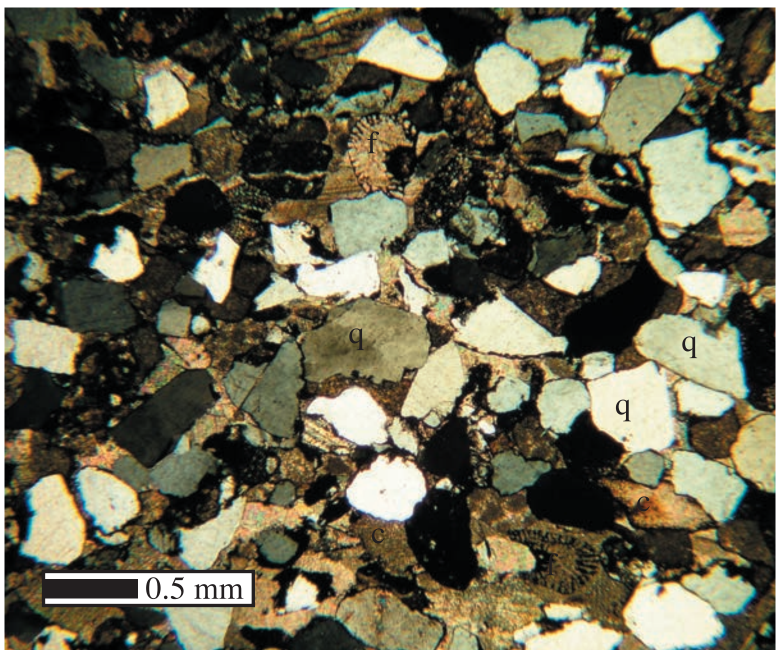
The Chapman Ridge Sandstone was mapped from Cisco, Georgia, to Richland, Tennessee, where it exists in three belts of Middle Ordovician rocks (Fig. 3-1). The sandstones become generally less ferruginous, thinner, and less cross bedded to the south in each belt, although there are local exceptions. The eastern depositional belt (Tellico-Sevier belt) lies in the hanging wall of the Chestuee/Dumplin Valley/Wildwood faults. The middle belt lies in the hanging wall of the Knoxville fault extending north from Cleveland, Tennessee, in the Athens syncline and ending in a fold near Willardtown, Tennessee. The western belt of Chapman Ridge Sandstone lies in the Saltville thrust sheet between Sweetwater and Richland, Tennessee.

Chapman Ridge Variability in Different Thrust Sheets

In the eastern Tellico–Sevier belt, the Chapman Ridge sandstones are thickest, most iron-rich, and contain the most cross beds with occasional interbedded shale, siltstone, and limestone. The best classic examples of Chapman Ridge Sandstone are found primarily between Etowah, Tennessee, and the Little Tennessee River in the eastern belt, and near Knoxville along the Tennessee River in the middle belt. Thin sections of samples collected south of Englewood, Tennessee, along TN 36 in the easternmost depositional belt contain angular to sub-rounded quartz grains with calcite cement and many fossil fragments (Figs. 3-4 and 3-5). Grains tend to have a brown to reddish-brown hematite coating. This coating occurs both between grains of quartz and between quartz and calcite grains. Quartz grains reach a maximum size of 1 mm. To the south, the sandstones tend not to be as hematite-rich but are similar in grain size (Fig. 3-6) and gradually grade into interbedded shales and siltstones with occasional thick conglomeratic beds near the Georgia border. Occasional coarse conglomerate layers consist of a mix of older pebbles and cobbles sampling the section from the Ocoee Supergroup to Middle Ordovician Lenoir Limestone (Kellberg and Grant, 1956). Thin sections from Cisco, Georgia (Fig. 3-7) contain chalcedony, limestone, and shale pebbles in addition to much smaller calcite and quartz grains. To the north, the Chapman Ridge Sandstone becomes discontinuous sand lenses east of Sevierville, Tennessee, before disappearing into the Sevier Shale.



a)



b)

Figure 3-4. a). Photomicrograph in plane light of thin section of Chapman Ridge along Tennessee 36 south of Englewood, Tennessee. Hematite is present as dark brick red to brown rims on grains. Quartz(q) is white in this view. Calcite(c) is mottled peach to brown. b). Plane polarized light thin section photograph of Chapman Ridge. This sandy limestone contains about 50% quartz grains, 40% sparry calcite cement, and 10% fossil fragments(f) and other grains, Quartz grains show undulose extinction as greenish gray, gray, black and clear grains.

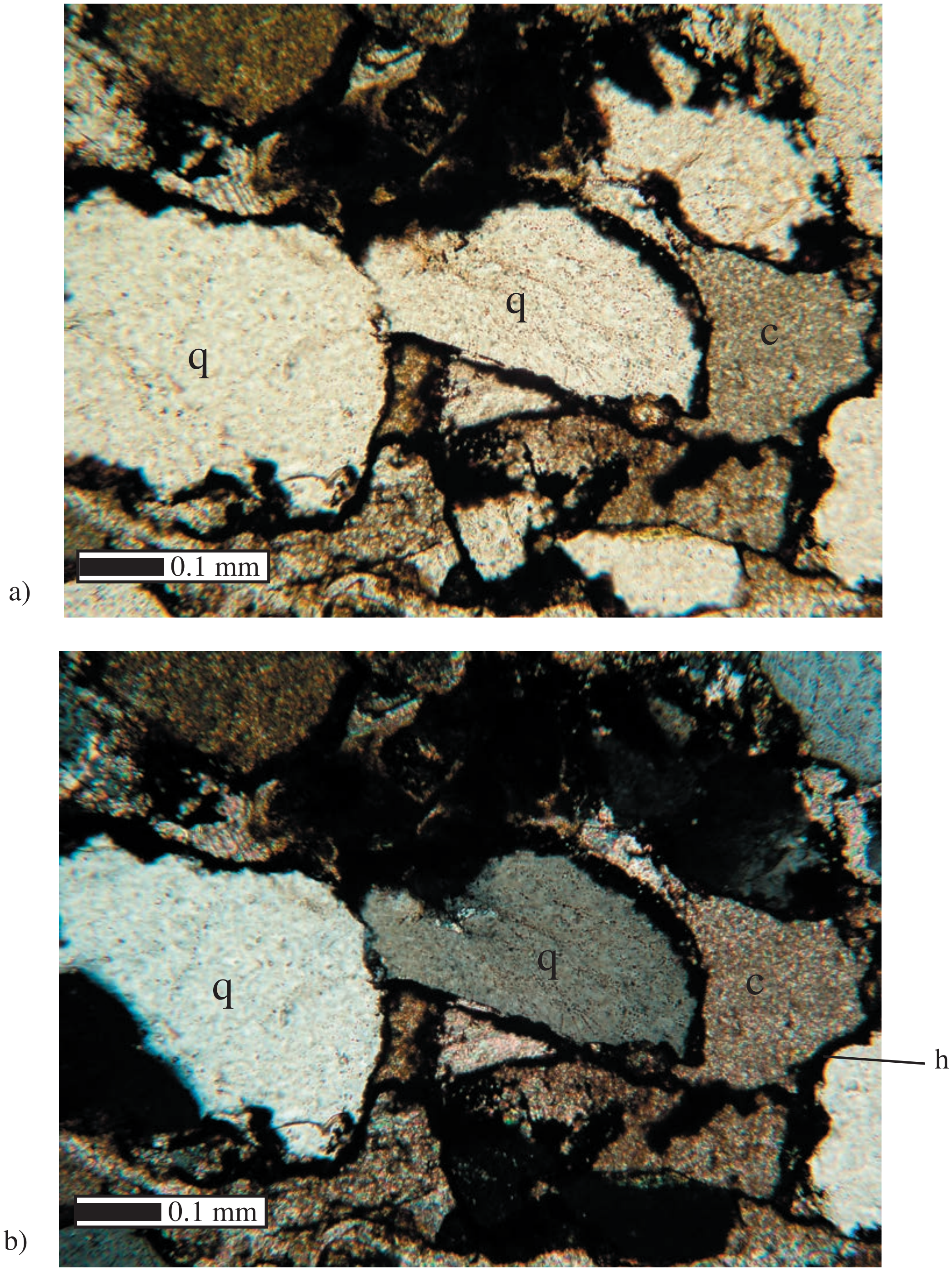
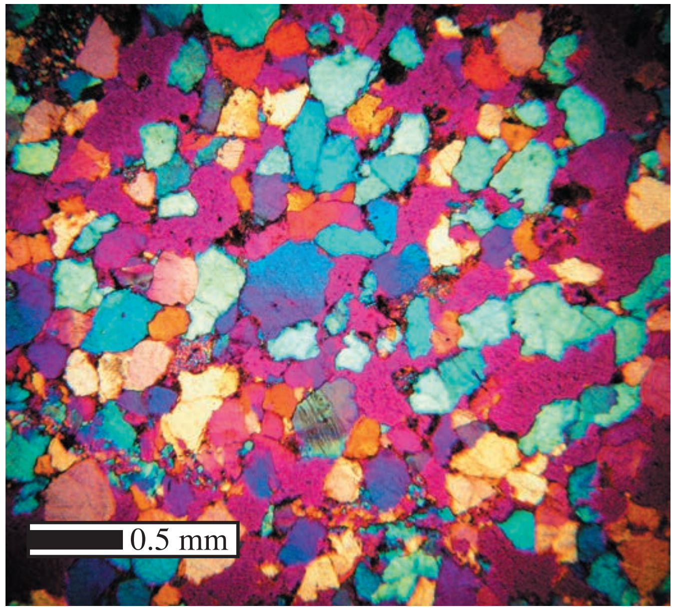


Figure 3-5 a). Photomicrograph in plane light of thin section of Chapman Ridge along Tennessee 36 south of Englewood,Tennessee under 16 x magnification. This thin section of sandy limestone contains about 50% quartz. Quartz(q) is white, calcite grains(c) are mottled gray, peach and orange. Hematite(h) consists of dark brick red to brown rims on grains and amorphous masses, especially between calcite grains. b). Photomicrograph in plane polarized light. Quartz grains show undulose extinction as greenish gray, gray, black and clear grains.

a)



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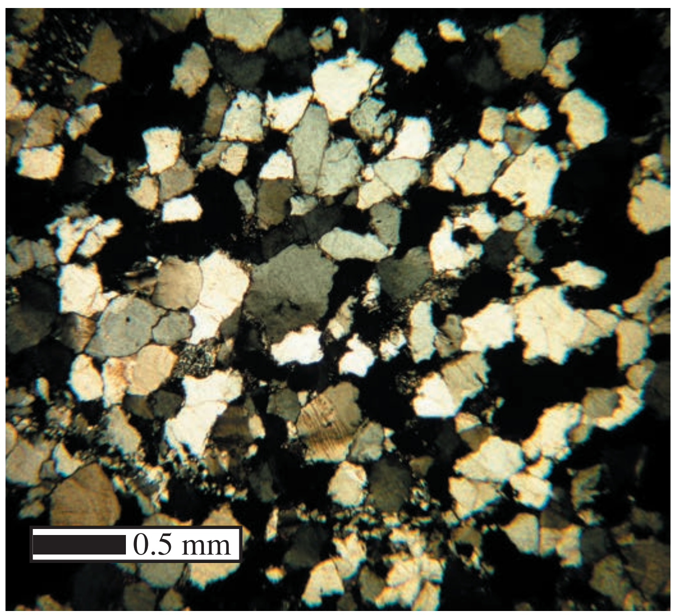
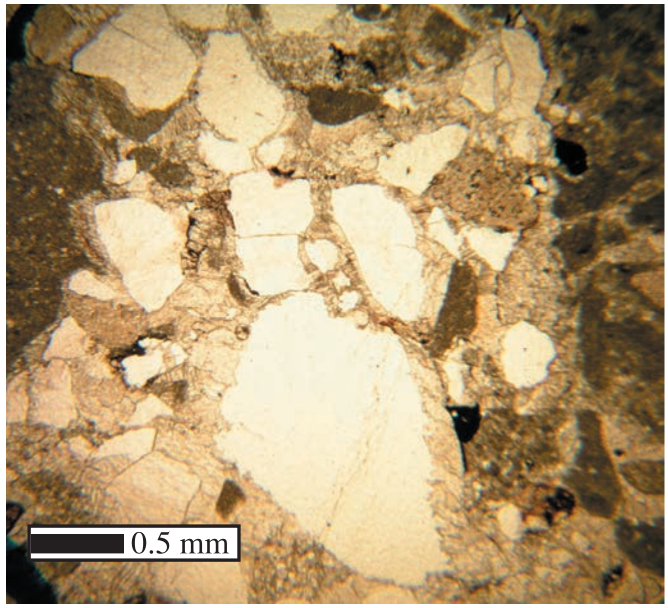


Figure 3-6. a). Polarized light photomicrograph of Chapman Ridge Sandstone thin section with gypsum plate from U.S. Highway 64 west of Parksville Dam (lack of contrast between quartz grains in plane light made this technique necessary to differentiate individual grains). This thin section of sandstone contains about 90% quartz grains. b). Photomicrograph in plane polarized light. Quartz grains show undulose extinction as greenish gray, gray, black and clear grains.

a).



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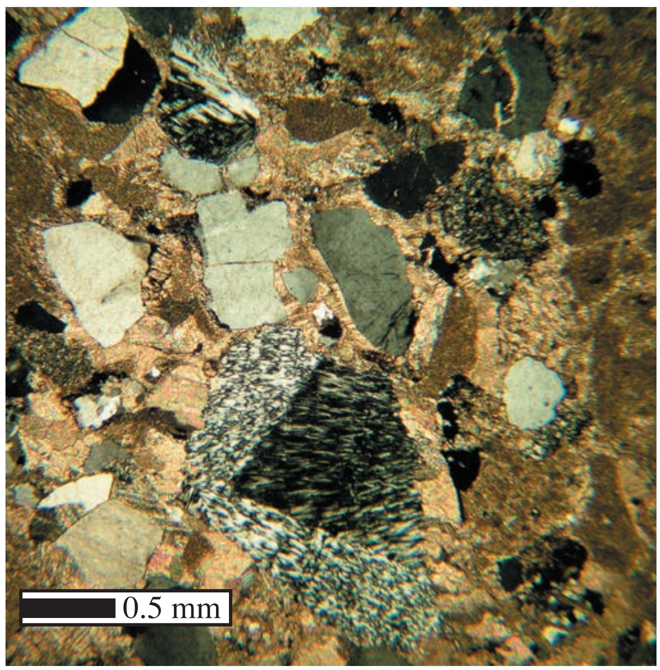


Figure 3-7. a). Photomicrograph in plane light of thin section of Chapman Ridge conglomerate east of Cisco, GA along Georgia Highway 2. Very little hematite is present in this thin section. b). Photomicrograph in plane polarized light. Thin section contains conglomeratic fragments of limestone, sandstone, shale, lithic fragments, and chert (large grain at center bottom, also smaller one in upper left). Quartz grains show undulose extinction as greenish gray, gray, black and clear grains.

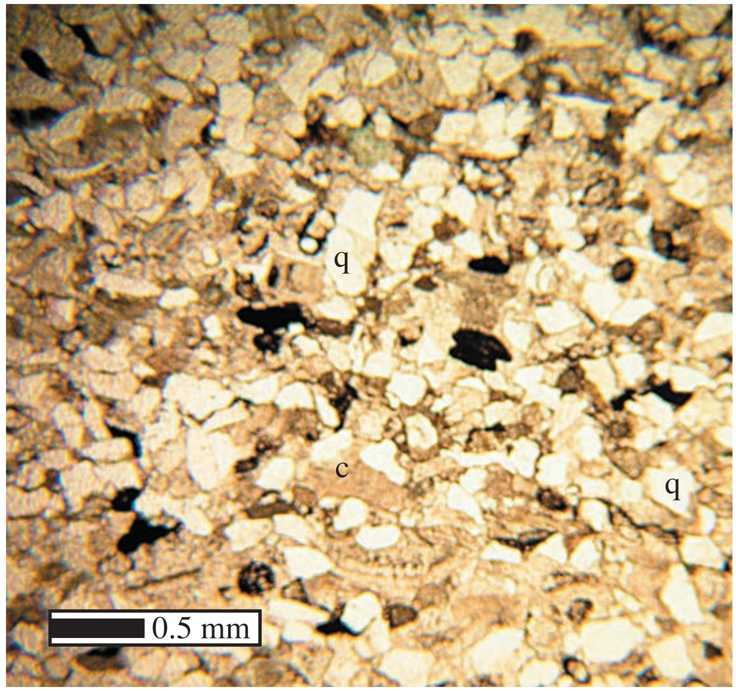
The Chapman Ridge in the middle belt consists of cross-bedded, ferruginous sandstone as well, although it is not as hematite-rich or consistently as thick as in the Tellico-Sevier belt, especially in southern part. The rocks occupying the southern part of the middle belt at the Chapman Ridge horizon are thin interbedded sandstone to quartz arenite and shale with sparse cross bedding, while to the north the traditional cross-bedded, ferruginous, sandy Chapman Ridge still exists, but tapers to a feather edge northwest of Willardtown, Tennessee. Thin sections of rocks collected along Chapman Highway just south of downtown Knoxville, Tennessee, contain a mix of subangular quartz grains, calcite, and a few fossil fragments (Figs. 3-8 and 3-9). Thin sections demonstrate the general westward fining of quartz grain size and the general increase in calcite content.

The western belt contains mainly interbedded thin-bedded sandstone with few cross beds and shales, and low concentrations of hematite.

Environment of Deposition

It is generally agreed that after flooding the Middle Ordovician unconformity, deposition (Lenoir, Murfreesboro, Poteet, Camp Nelson) resumed at the passive continental margin. The influx of clastics (Athens, Sevier, Bays) is the result of docking arc terranes during the Taconic orogeny.

The Chapman Ridge Sandstone depositional environment has been a source of debate for some time. While it is generally agreed the Chapman Ridge was deposited in a nearshore marine environment during this time, numerous models have been proposed to describe this environment. Rodgers (1953) suggested the Chapman Ridge was deposited in a subaerially exposed tidal flat with perhaps a single river providing the source material. Neuman (1955) thought the Tellico Sandstone (part of the Chapman Ridge herein) was the front of a mass of material transported by turbidity currents, which was affected by normal marine bottom currents. He felt that there was a lack of widespread



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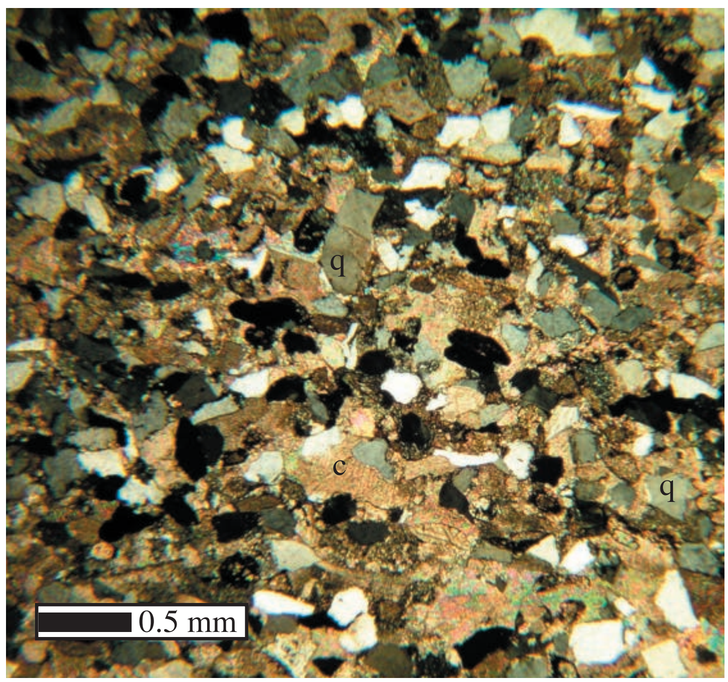
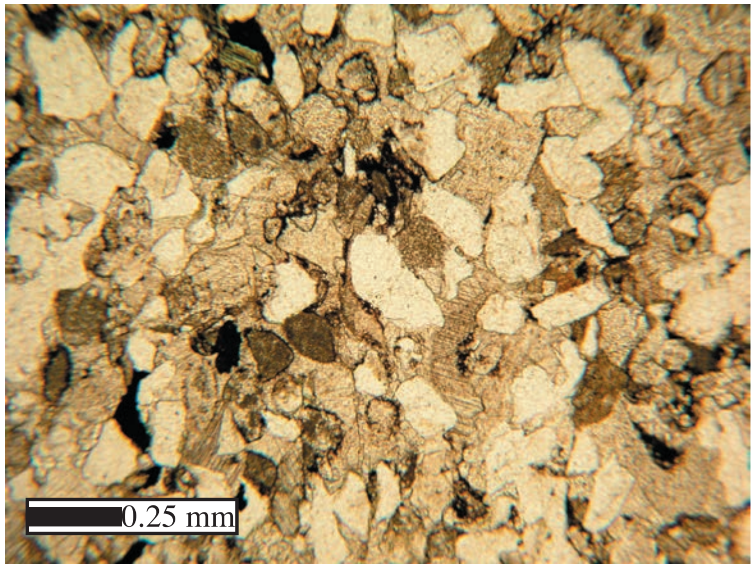


b)

Figure 3-8 a). Photomicrograph in plane light of Chapman Ridge Sandstone from along Chapman Highway just south of downtown Knoxville, Tennessee. White grains are quartz(q). Calcite(c) is peach to light brown and mottled. Hematite is present as dark brown rims on grains. b). Photomicrograph in plane polarized light This thin section of sandy limestone is predominantly calcite with about 30 % quartz grains. See Fig. 3-9 for more detailed view of hematite rims.

a) 

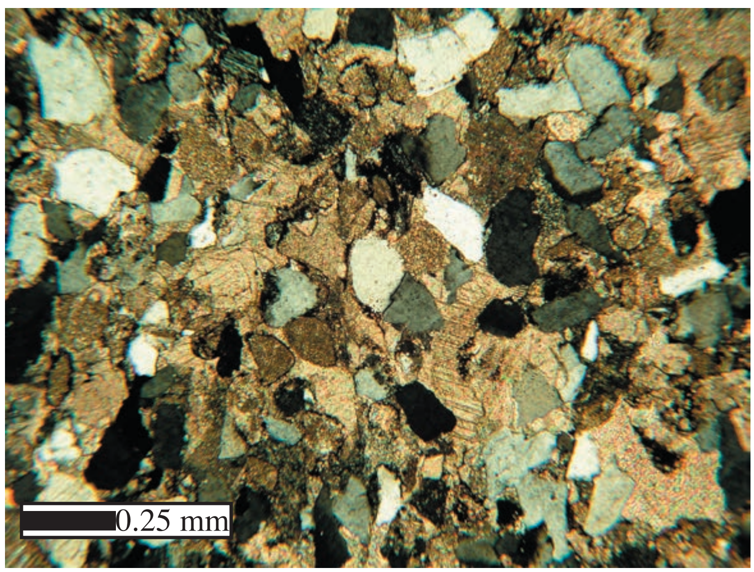
b) 

Figure 3-9 a). Photomicrograph in plane light of thin section of Chapman Ridge along Chapman Highway just south of downtown Knoxville, Tennessee at 6.3 x magnification. Calcite and fossils are peach and brownish gold. Hematite is in dark rims with slight reddish tint on grains. This thin section of sandy limestone is predominantly calcite with about 30% quartz grains. b). Photomicrograph in plane polarized light of thin section. Quartz (white, gray and black grains in photograph) in various stages of extinction. Calcite is mottled peach colored mineral.

cross beds in the Chapman Ridge, the presence of interbedded lime reefs (suggesting a below wave-base depositional environment), and little evidence of turbidites (so the deep deposits must have been disturbed by marine bottom currents). Neuman (1955) also proposed that, despite its lithologic similarity to the underlying Chapman Ridge, the Chota Formation is probably a shallow water deposit that was periodically subaerially exposed.

Occasional coarse conglomerate layers consisting of a mix of older pebbles and cobbles were cited by Kellberg and Grant, (1956) as indicative of stream deposits emptying into the sea that could also be reworked by turbidites. Kashfi (1971) and Smith (1976) proposed that the Chapman Ridge was deposited in a deltaic environment with multiple channels cutting across limey flats. Bryozoan- and crinoid-rich limestone reefs grew in areas without active channels. As the channels moved and their effluent was dumped into the shallow reef systems, the carbonates were drowned in sediment, accounting for the observed facies changes. McWilliams (1975) analyzed the Chapman Ridge near Athens, Tennessee, and decided that it was deposited in barrier islands, shallow subtidal marine sand flats, and tidal channels analogous to the Bahamian sandbanks. According to Walker et al. (1983), the Chapman Ridge in the southeastern depositional belt represents a facies of shallower water clastics prograding basinward (northwest) over underlying turbidites derived from a southeastern source. Basin models of Walker et al. (1983) show the Chapman Ridge as a nearshore terrigenous derived sandstone to the east but as turbidite deposits near Knoxville. Recently, Thigpen (2002) suggested a possible longshore current depositing Chapman Ridge Sandstone above the Athens Shale (Fig. 3-10), in relatively shallow water.

An isopach map of the Chapman Ridge Sandstone was created using thicknesses from my maps and other published geologic maps across the outcrop extent of the unit (Fig. 3-11a). This map was palinspastically restored using deformation estimates from

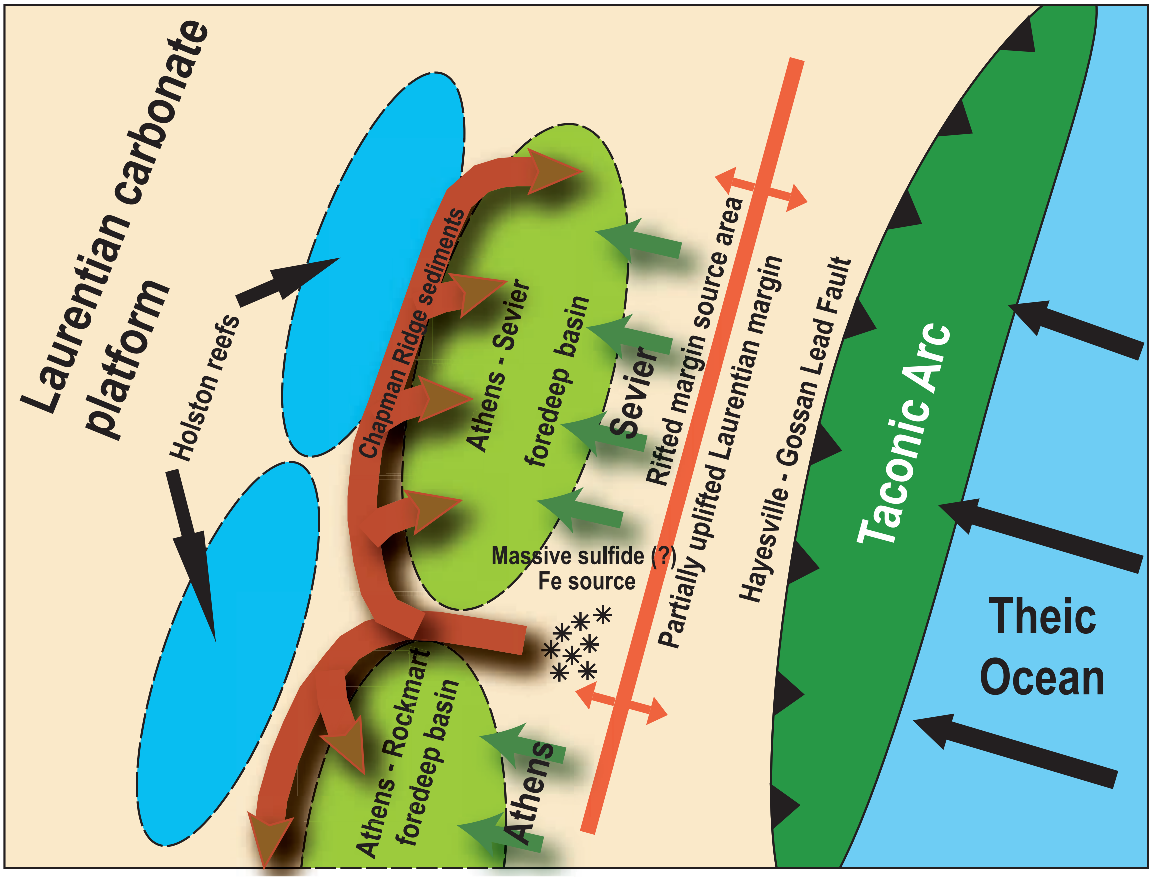


Figure 3-10. Model for source and by-pass sedimentation of the coarse quartz and hematite in the Chapman Ridge Sandstone. Also shows erosion of rifted-margin sediments in the western Blue Ridge during Taconic uplift, along with Athens-Sevier turbidites. From Thigpen (2002).

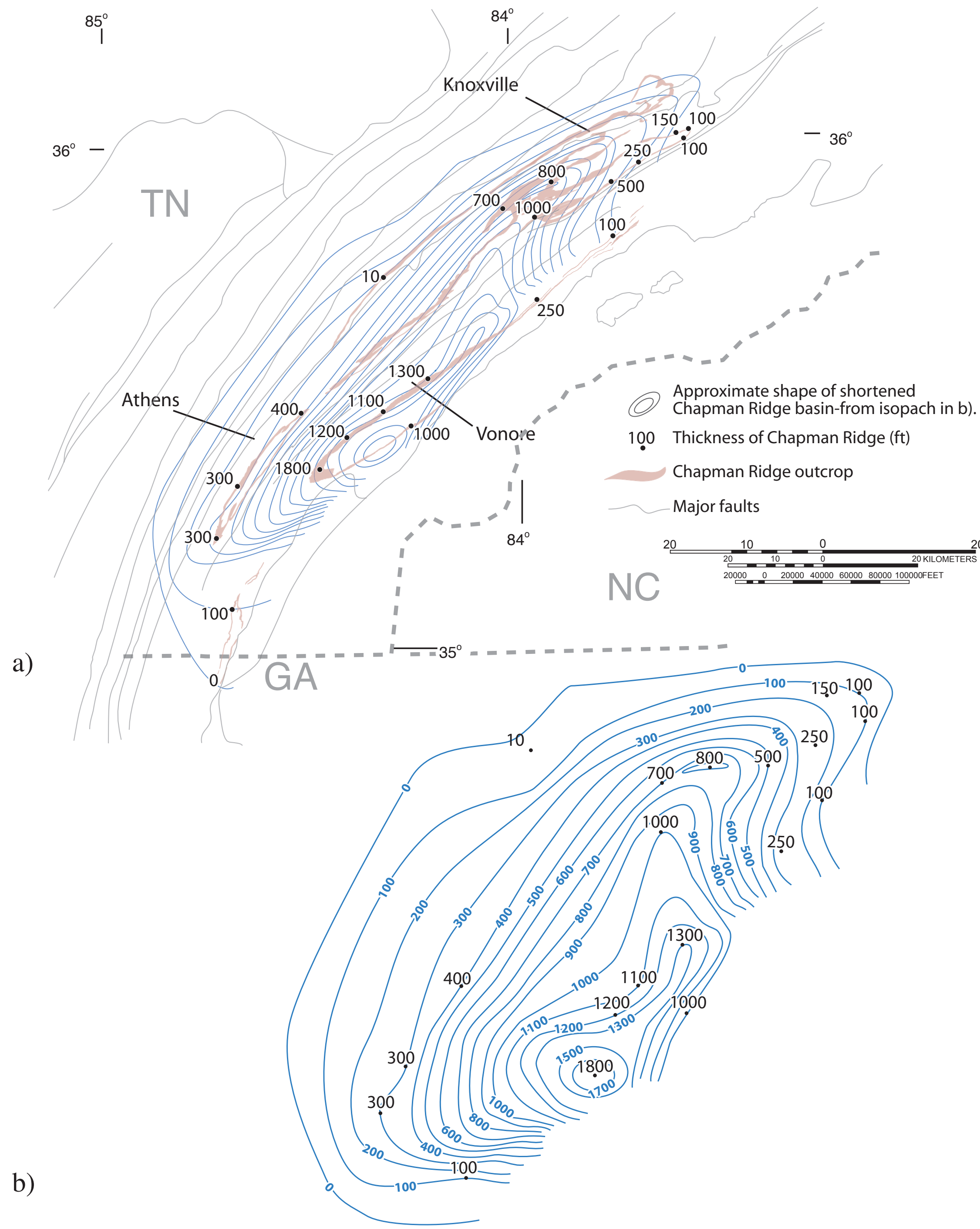


Figure 3-11. a) Thickness of Chapman Ridge Sandstone (reddish brown) at selected locations (thicknesses in feet). Superimposed on this is a Chapman Ridge isopach map (b) . b) Isopach map of palinspastically restored Chapman Ridge Sandstone lengthened by 54 percent NW-SE to provide a view of the undeformed basin shape. Shortening amounts taken from Whisner et al. (2004).

Whisner et al. (2004) to show the approximate size and shape of the undeformed basin (Fig. 3-11b).

Cross-Bed Data

Data were collected to determine the direction of the source area of the Chapman Ridge Sandstone using paleocurrent analysis. Cross beds were measured at 50 stations in the three Chapman Ridge belts to determine if a uniform current direction existed such as that caused by longshore currents, or other systematic paleocurrent directions (Fig. 3-12). Five to ten cross-bed directions were measured at each station (Appendix II). The plotted data suggest cross-bed orientations have a weak southeast directionality distributed along all belts of Chapman Ridge (Fig. 3-13). Many locales reveal directional variability at different stratigraphic levels within a single outcrop.

Hematite Origin

Analysis of hematite cement in the Chapman Ridge Sandstone could increase our understanding of basin dynamics. Hematite deposition occurs in varying degrees throughout the Chapman Ridge Sandstone. Hematite stain intensity (depth of color) was mapped and palinspastically restored using the basin isopach map (Fig. 3-14) on the assumption that stain intensity could be proportional to hematite concentration and could indicate proximity to its source.

According to Mücke (1994), numerous ideas have been proposed to explain the occurrence of hematite in sandstones, most of which focus on the relative timing of iron enrichment relative to diagenesis. He suggested one or more of the following factors control iron deposition: (1) diagenetic alteration of iron source rocks freeing transportable iron; (2) changes in available porosity in a sandstone (increasing grain size increases porosity and available space for cement deposition by iron-rich waters, Turner [1974]), and (3) variation in iron oxidation state and the availability of iron-bearing clays and other iron minerals, especially in near surface conditions (Fig. 3-15). The precipitation

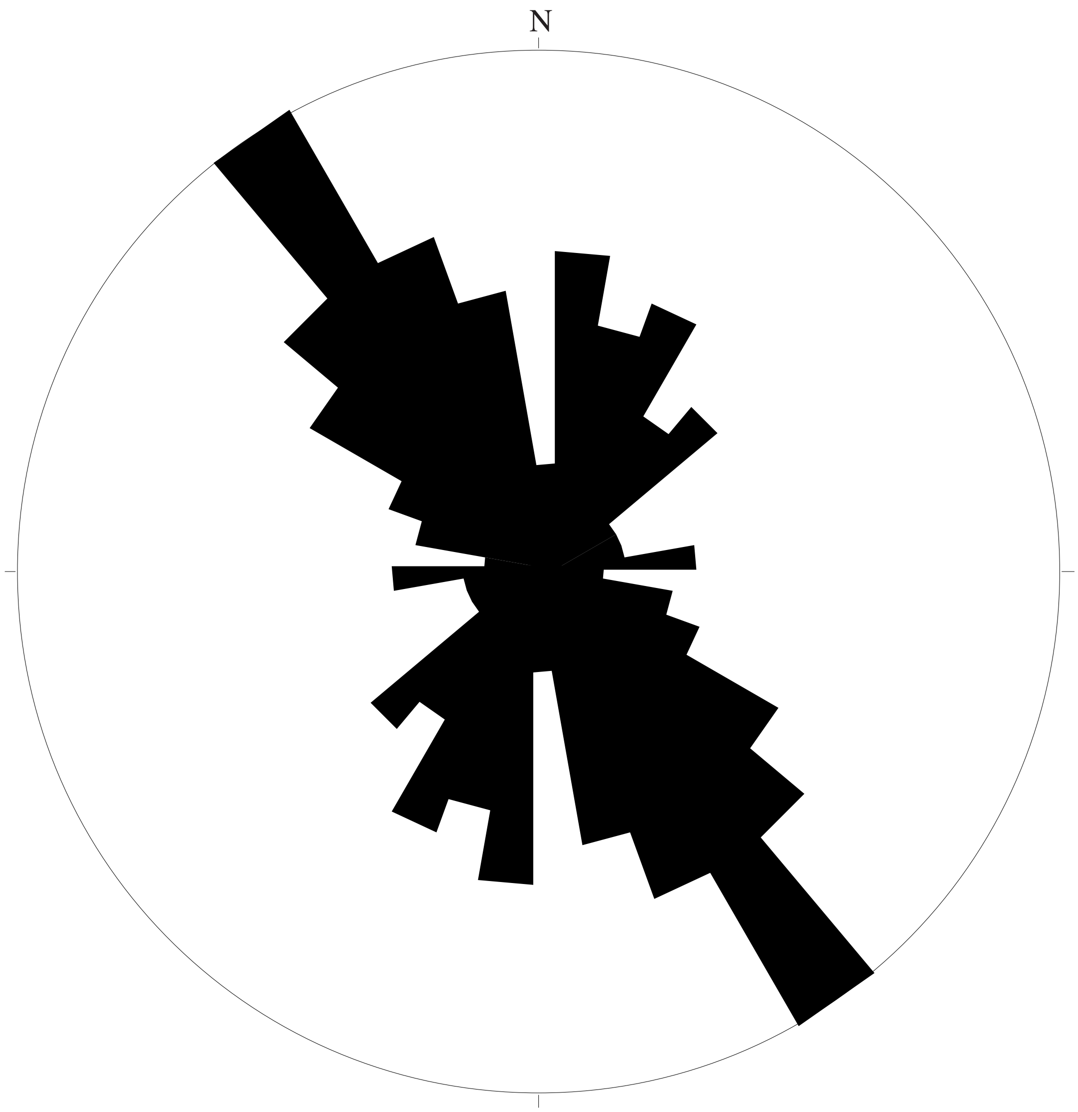


Figure 3-12. Rose plot of 162 paleocurrent directions. Outer circle diameter is 9%. Petal width is 10^{o}. Note weak trend of cross-bed directions toward the southeast.

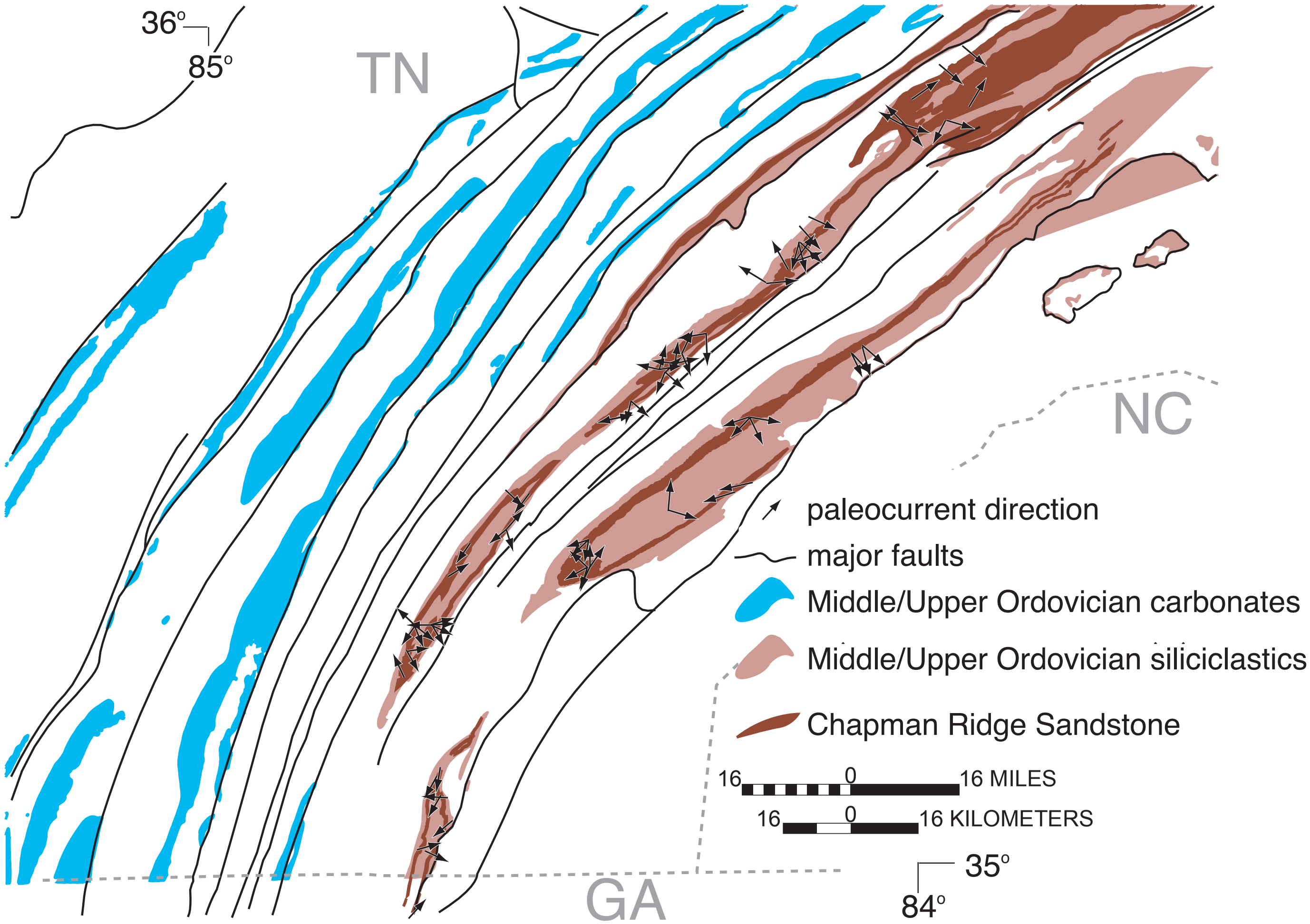


Figure 3-13. Locations of cross-bedding measurements in Chapman Ridge Sandstone across East Tennessee showing paleocurrent directions.

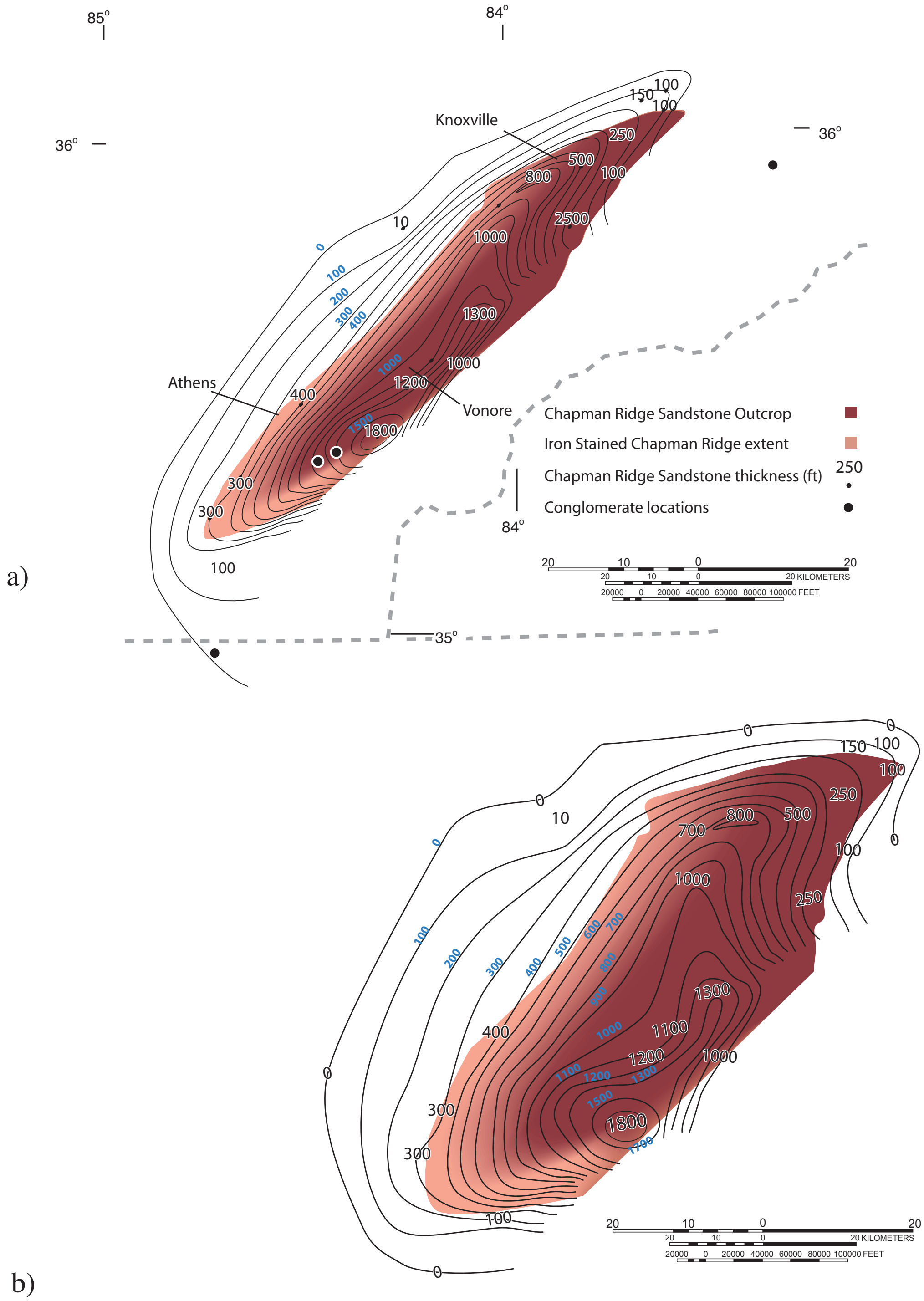


Figure 3-14. a) Extent of hematite staining in the Chapman Ridge sandstone based on observations at sampling localities and thin sections. A gradual decrease in hematite to the south and northwest is indicated. Darker red is more hematite-rich, lighter red is less. White is little to no hematite. b) Palinspastically restored basin showing approximate size of hematite-rich zone. There is some correlation of unit thickness with hematite staining intensity. Isopach map is same as Fig. 3-11.

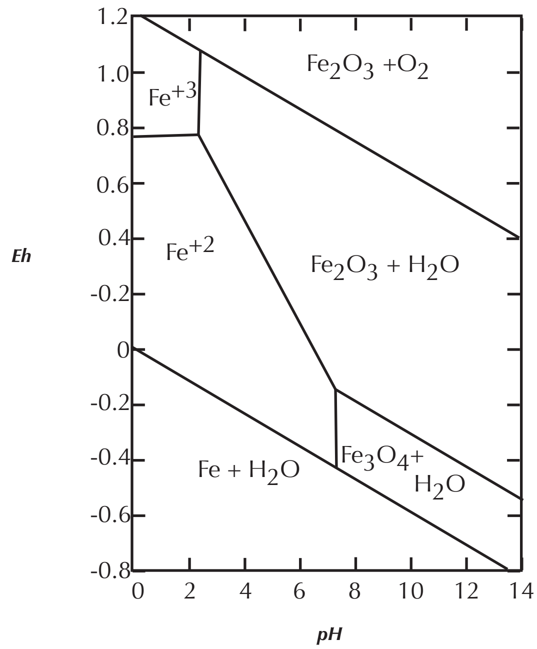


Figure 3-15. Stability field of iron in different oxidation states under different Eh and pH conditions. Hematite [Fe_2O_3] is stable over a wide range of redox and pH conditions. (From Garrels, 1960).

reaction of hematite from aqueous solution is

$$2Fe^{2+} + 3\ H_2O \Rightarrow Fe_2O_3 + 6H^+ + 2e^-$$

$$\Delta G^\circ_R = +\ 30.161 \quad E = +\ 0.65\ V$$

Moderate hematite precipitation is achieved in a slightly acidic to alkaline environment (seawater pH = 7.5) even in a weakly reducing environment (Fig. 3-15). Many factors such as climate; mixing of meteoric, stream, and ocean water; tectonic setting; depositional environment; and diagenetic effects also affect iron transport, external conditions leading to iron precipitation, and stability of iron minerals.

Three primary models of iron enrichment have been proposed for terrestrial sandstones; 1) Walker (1967) suggested diagenetic alteration of interstitial clays that occupy or have been transported to open spaces within sandstones could provide an iron source. These clays and iron-bearing minerals are then decomposed by groundwater, forming hematite, which precipitates in oxidizing environments. 2) van Houten (1968) suggested that a post-depositional environment leaching iron from the overlying sediment of iron-rich minerals and clays relatively close to the surface and iron concentration on some impermeable surface by dissolution in groundwater could form iron-enriched cements. 3) Mücke (1994) proposed that decomposing organic material mobilizes iron by creating a reducing environment. The resulting iron-enriched water flows down into the pore spaces of the existing rock where local oxidizing conditions cause the iron to precipitate. Other possible mechanisms for iron oxide deposition also involve changes in water chemistry. Iron deposits in Alabama and the Clinton ores of the central Appalachians are thought to have been deposited by streams draining into restricted lagoons where changes in water chemistry caused iron oxides to precipitate (Hunter, 1970; Sheldon, 1970). Iron deposition is also common in modern lakes in Norway, which have restricted deep portions with anoxic conditions (Hongve, 1997).

It is very difficult to uniquely determine the source or sources of iron in sedimentary rocks due to the potentially complex interplay of factors affecting iron mobilization, speciation, transportation, the wide stability range of ferric hydroxide [$Fe(OH)_3$], the most common precursor to hematite, and the wide stability range of hematite (Fig. 3-15) a common iron oxide cement.

The presence of iron oxide in the Chapman Ridge has generally been attributed to draining of iron-rich Taconic highlands. McWilliams (1975) assumed that if the iron were derived from a terrestrial source, the source must have been close to the location of its ultimate deposition. He disagreed with the terrestrial iron source hypothesis, stating quartz grains contained within the Chapman Ridge are too mature to have a nearby (iron-rich) source. He gave no alternative explanation for hematite deposition, except to say that he thought it was deposited contemporaneously with the sand. In addition, the depositional environment he proposed for the Chapman Ridge (open water-barrier islands) makes restricted basin hematite deposition difficult. Thigpen (2002) suggested another source of iron: longshore currents bringing hematite-rich waters from black smokers similar to what have deposited the sulfide in the Ducktown mining district from a bypass channel between barrier islands (Fig. 3-10). A biogenic mechanism fixing iron could be another option. In some modern iron formations, bacteria extract iron from water with very low concentrations and concentrate it as ferrihydrite (Fe_5O_7OH) (which alters to hematite) in algal mats in shallow water deposits (Brown et al., 2001). This would allow terrestrially sourced iron in very low concentrations from a distant source to be microbially concentrated. A biogenic source is not necessarily needed, however. Drainage of a region containing trace amounts of iron could have provided enough Fe^{3+} to create hematite cement. Mücke (1994) showed as little as 0.1 weight percent of extractable iron can color sandstones.

Rounded hematite nodules observed in thin section have a variety of possible origins. Primary deposition as cementing medium is possible, although the majority of the Chapman Ridge is cemented by calcite with accessory hematite. Hematite can also be a secondary diagenetic replacement for iron-rich minerals and clays that were part of the matrix in the sediment. There is evidence for both means of deposition. In some thin sections, hematite occurs as masses surrounded by relatively unaltered (non-serrated grain boundaries) calcite and quartz grains. In others, hematite occurs as irregular masses filling or even replacing dissolved grains along grain boundaries/crystal faces.

The origin of hematite cement in Chapman Ridge sandstone is of interest because if it is local, it could provide evidence of a sediment source and transport paths creating the Chapman Ridge and thus constrain basin architecture. Unfortunately, hematite cement results are equivocal; in some cases the small amount observed in Chapman Ridge thin sections could have originated as alteration of detrital clays (rather than synsedimentary precipitation and deposition) and, where precipitated, could have originated in rocks with very low weight percent iron (i.e., it does not have to originate in iron-rich waters such as black smokers). These qualities are not distinctive enough to permit inference of a specific sediment source or transport paths.

Chapman Ridge Depositional Environment

The portion of the Tellico-Sevier basin into which the Chapman Ridge Sandstone was deposited was probably not deep, given the amount of existing interbedded reef limestone. Chapman Ridge features such as mudcracks indicate occasional subaerial exposure, and changes in grain size both up section and across beds could be explained by deposition near a migrating river mouth or in a wave-dominated environment. Cross-bed measurements show a weak but dominant southeast-northwest trend, with trends fanning from the northeast around to the southwest. This pattern could be the result of longshore or wind-driven currents modifying a predominantly offshore flow or it may simply reflect deposition in shallow meandering channels. The conglomerates described by Kellberg and Grant (1956) could mark the locations of submarine valleys, deep tidal channels within a broader shallow shelf environment or influx channels draining highlands. Perhaps they mark a high point in amount of erosion of the highlands. The limited extent of the Chapman Ridge suggests that it may have originated from a single river emptying into a shallow marine environment. Mature quartz in the volumes necessary to deposit a continuous lithostratigraphic unit with a minimum width of 32 km (20 mi) suggests the river and its drainage basin must have been large. It is unclear, however, what source this river might be draining; nearby units such as the Knox Group do contain silica, although most of the silica in the Knox is chert, and the majority of Chapman Ridge sand grains are not chert. Rifted margin and basement rocks similar to those exposed in the present day Blue Ridge would be an excellent source of sand grains. Kellberg and Grant (1956) observed that as much as 60 percent of conglomerate clasts at the Fincastle locale were likely derived from rocks of Chilhowee age or older, and that the same rocks were the source of between three and ten percent of clasts in more southerly conglomerates.

Discussion

What is the source of the Chapman Ridge Sandstone, and what are the implications for development of the Tellico-Sevier basin? Conventional wisdom (Benedict and Walker, 1978; Shanmugam, 1978; Walker et al., 1983) dictates that as a classic foredeep basin, the Sevier basin should contain sediments derived from the Taconic highlands that were approaching from the east, loading the crust, and initiating basin formation. Rodgers (1953), Kashfi (1971), and Walker et al. (1983) suggested the source of the Chapman Ridge was a crystalline complex to the southeast, or "tectonic land" (from Shanmugam, 1978). Chapman Ridge paleocurrent data plus Middle Ordovician stratigraphic relationships documented in this study support an easterly sediment source. According to several lines of evidence, however, the source cannot be the Taconic arc.

Detrital zircon ages (Bream, 2003) indicate pre-Paleozoic (1.1 Ga and older) zircons occur in the Sevier Shale (Hardeman et el. [1966] usage), although Paleozoic zircons are not present. The pre-Paleozoic zircons must have originated in Rodinian rifting-related sediments. Therefore, the Taconian clastic wedge contains no Taconian zircons. (This age is based on data from a single location in the Sevier along U.S. Highway 321 near Walland Tennessee; and more zircon data from other locations in the Sevier formation are needed to conclusively establish zircon provenance). Thomas et al. (2004) also noted a lack of synorogenic zircons in the Taconic, Acadian, and Alleghanian clastic wedges. Kellberg and Grant (1956) suggested the majority of the conglomeratic pebbles and cobbles may have been deposited near shore and then redeposited into deeper water along a trough, and likely came from the sedimentary rocks underlying the Chapman Ridge, not from an approaching arc. Kellberg and Grant (1956) observed that the bulk conglomerate clast composition (limestone) is representative of the surrounding units (i.e., they had the same source area), and that the conglomerate clasts represent units from Lenoir Limestone downward to the Ocoee Supergroup, with limestone fragments derived from the Upper Cambrian to Lower Ordovician and the sandstone and siltstone fragments from the Middle and Lower Cambrian. Polysynthetically twinned K-spar clasts observed by the author in some thin sections also suggest that older rocks (Rome [Samman, 1975], Chilhowee Group, and Ocoee Supergroup [King, 1964]) are the source of some sand grains. There is no evidence of the volcanic clasts that would be expected from an approaching Taconic arc. Mack's (1985) provenance study of the sandstones of the Blount clastic wedge expanded the work of Kellberg and Grant (1956) from relatively rare conglomerates to the more extensive sandstones of the Athens, Bays, Chota, Tellico, and Sevier formations from Cisco and Dalton, GA and Sevierville and Walland, TN. This study shows siliciclastic particles from various sandstones within the basin were derived from platform rocks (Mack, 1985), not Taconic plutonic and volcanic rocks. A lack of volcanic derived clays (Andersen, 1995) in the Blountian Sevier basin also indicates that the source of the clay in the Sevier basin was probably not Taconic arc-derived. The Taconic basin, formed later during the same orogeny, contains clays with high mafic components (Andersen, 1995).

Leroux (1974) in the Tellico-Sevier syncline and Smith (1976) in the Calhoun area suggested Chapman Ridge sediments were coming not from Taconic highland to the east, but from unidentified sources along strike, as reworked alluvial deposits were transported northeast by longshore currents. Unfortunately, neither provided the supporting paleocurrent data or suggested a specific source for the sediment.

The source for sediments in the Sevier basin must be highlands that lie between the encroaching arc and the basin, and that have sufficient relief to prevent westward transport of Taconic arc-related sediments.

Hatcher et al. (2004) suggested the source of the Chapman Ridge was a peripheral bulge uplifted by thrust loading farther east that could also have blocked transport of volcanogenic sediment into the Sevier basin. Deposition of the Middle Ordovician clastic wedge, including the Chapman Ridge, may have occurred in a back-bulge basin similar to the westernmost part of the Taranaki basin, west of New Zealand (Holt and Stern, 1994). The size of modern back-bulge basins, however, is an order of magnitude smaller than the Sevier basin, but these modern analogues also involve collision of smaller arc systems rather than obduction of the Taconian arcs and distal Laurentian ocean floor. Formation of back-bulge basins has been proposed for other areas of the Appalachians. For instance, a developing back bulge is cited as the reason for Devonian pinnacle reef development in New York (Ver Straeten and Brett, 2000); as the bulge passed, water depth decreased to the point where conditions were favorable for reef development.

Reefs continued to exist at this location even as water depth increased as the bulge moved away. The Taconic peripheral bulge would have to be four times greater than any modern bulge to exhume a minimum of 1500 m (5000 ft) of rock, removing the overlying passive margin sequence to expose rifted margin sediments and underlying crystalline basement (the sources for Chapman Ridge sands). In addition, the Middle Ordovician Blountian basin into which the Chapman Ridge Sandstone eventually was deposited contained as much as 3000 m of sediment. Flexural and basin modeling show that lithospheric loading by a docking Taconic arc does not produce substantial flexure beyond the peripheral bulge (Fig. 3-16). Any subsequent back-bulge basin is at most only a few hundred meters deep (i.e., no back bulge basin of any size). Some structure must have blocked westward transport of sediment from the obducting Taconian arc, and exposed to erosion the entire Taconic stratigraphic column down to the Ocoee Supergroup. This is consistent with the work of Thomas et al. (2004), which concluded the Alleghanian clastic wedge in East Tennessee contains mid- and early Paleozoic zircons (Fig. 3-17).

Bayona and Thomas (2003) suggested that the migrating Taconic forebulge settled under the Birmingham graben, where reactivation of basement faults permitted higher than expected relief, and deeper than expected erosion of sediments into the Middle Ordovician basin in Alabama and Georgia. If the graben were continuous into Tennessee, it would lie under the westernmost Blue Ridge, an appropriate location for the Tellico-Sevier basin. But even the unexpectedly deep erosion in the graben (down into the Knox group) is insufficient to produce the Lower Cambrian clasts in the Chapman Ridge. In addition, seismic reflection data in Tennessee show no sign of a graben, and generally provide no indication of basement fault reactivation.

Andersen (1995) presented a model in which sediments in the Tellico-Sevier basin were derived from an outer arc of deformed continent-derived sediments deposited into the foredeep. The magmatic arc deposits sediment into a forearc basin that is separated

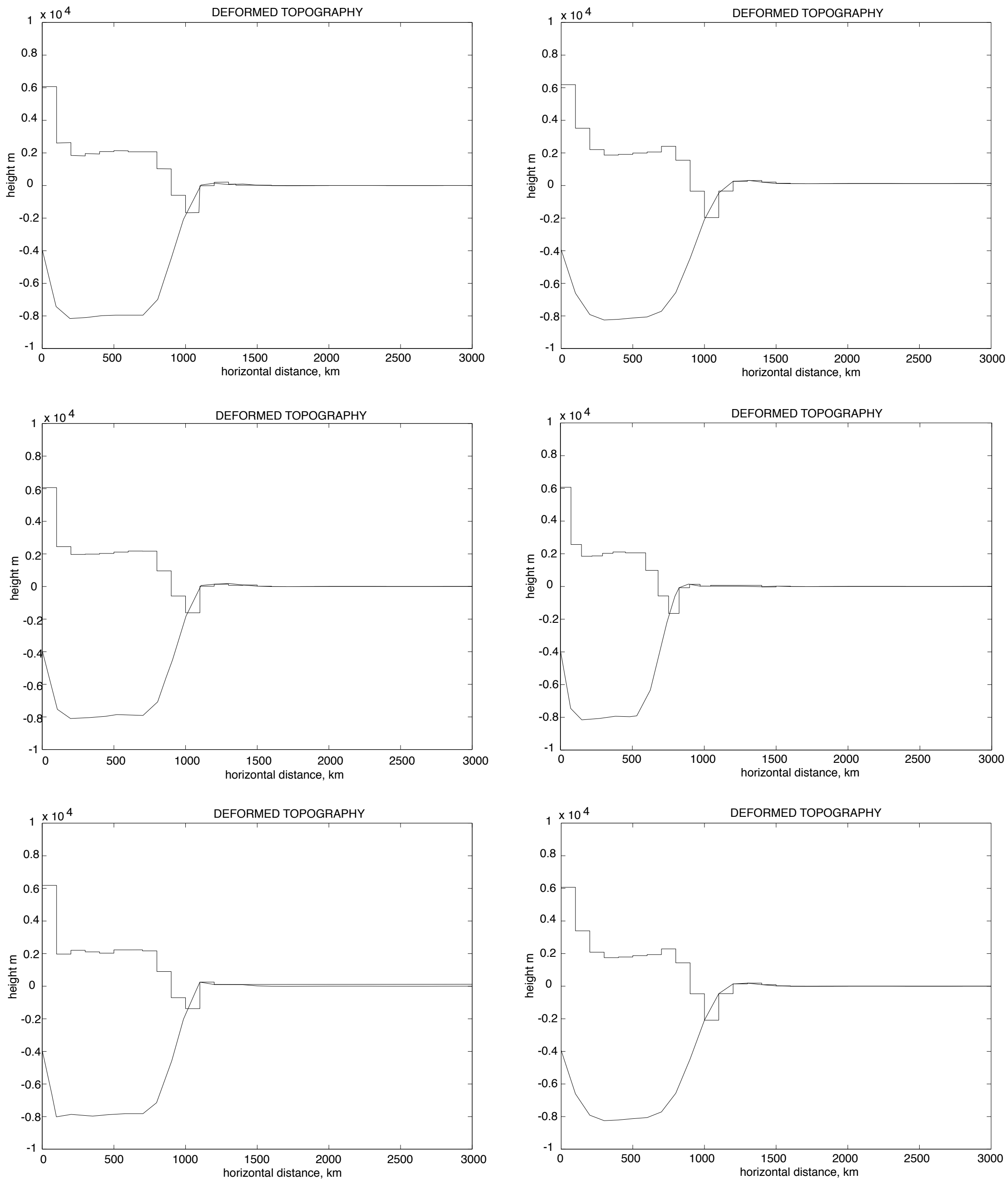


Figure 3-16. Lithospheric flexure modeling of crustal response to loading using MATLAB© plug-in by Nestor Cardozo of Cornell University. Models shown vary in load width and density, as well as in continuity, thickness and elastic properties (Young's modulus, Poisson's ratio) of the lithosphere. None produce a back bulge basin larger than a few hundred meters deep.

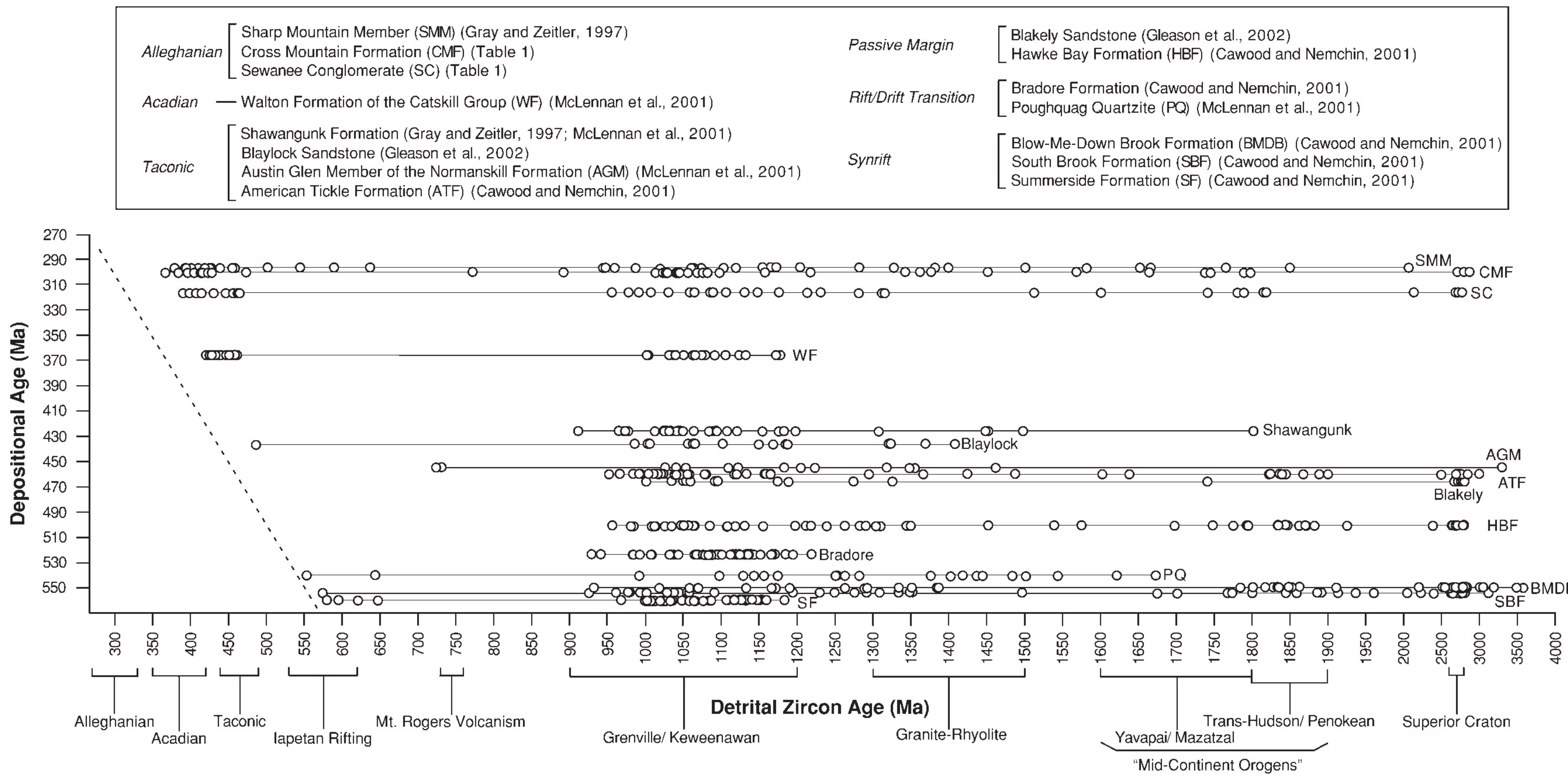


Figure 3-17. Detrital zircon ages (open circles) vs. depositional age of sediments in which they are found (from Thomas et al. 2004). Youngest detrital zircons within sediments tend to be from the previous orogeny. Diagram shows a lack of zircons derived from volcanogenic sources associated with orogenies concurrent with age of sediment deposits.

from the Tellico-Sevier basin by the outer arc until more complete arc accretion occurs and then it begins contributing sediment to the basin, perhaps by Bays time. The outer arc sediment blockage could have been overridden or buried under sediment.

The barrier/sediment source of the outer arc described by Andersen (1995) could also be part of a Taconic foreland fold-thrust belt (FTB). A FTB could have deformed and exposed the entire stratigraphic section from Lenoir to Ocoee Supergroup (as the entire stratigraphic section is exposed in the Alleghanian FTB and adjacent Blue Ridge). In fact, Bream (2003) suggested the drainage divide could be the eroded equivalent of the modern western Blue Ridge. The eroded remains of the Taconic FTB or rifted margin succession could subsequently have been overridden during the Alleghanian by the Blue Ridge, or parts of it could be preserved as pre-Alleghanian structures beneath the Blue Ridge. Unfortunately, existing seismic data that could support this are very poor.

Ricci-Lucchi (1986) suggested multiple modifications to basic foredeep with deformed basement rocks thrust sufficiently upward to divide the basins into complex geometries or even into separate smaller basins (Fig. 3-18). This possibility exists but is difficult to prove due to the lack of access to possible basin rocks under the Blue Ridge Province and the complicated nature of Taconic-related faults, such as the Greenbriar.

Do these complications indicate that our expectations of generally uncomplicated foreland basins are unrealistic, or perhaps that there is some quality specific to the rifted Grenville margin and overlying sediments in the Tennessee embayment that make it particularly likely to deform during collision?

Conclusions

Based on what I have observed during this study:

1. I believe the sand of the Chapman Ridge was the initial large pulse of coarser-grained siliciclastic sediment from highlands to the east and included older Paleozoic units that were deformed, exhumed, and reworked from the eastern

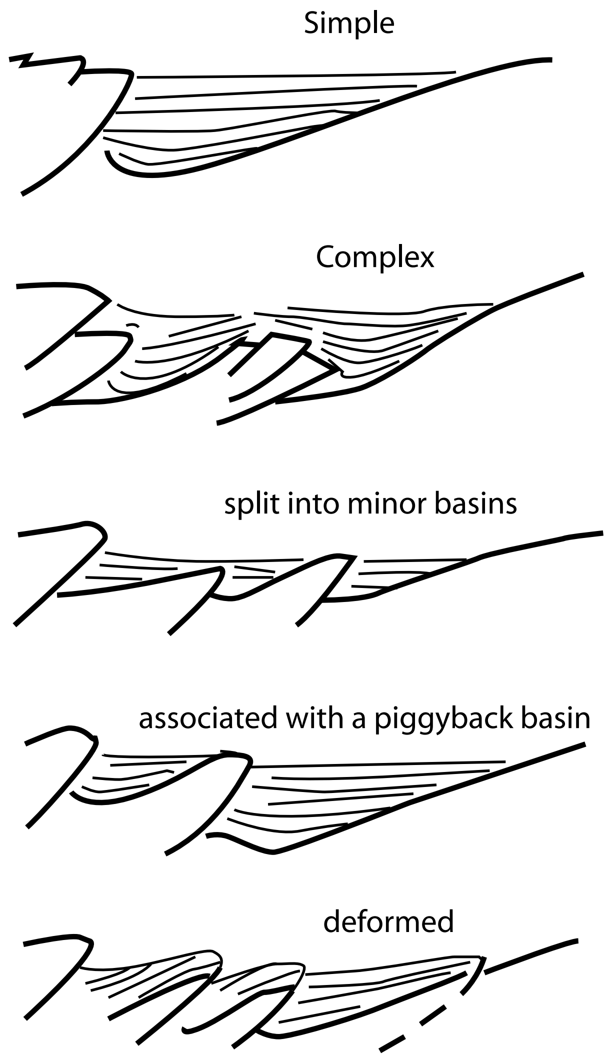


Figure 3-18. Models of basin types. Top is classic foredeep, traditional interpretation of Sevier basin. Complex basin model is proposed for Sevier basin in this paper. Minor basins and piggyback basins are associated with smaller basin types (from Ricci-Lucchi, 1986).

edge of the basin (now buried) (Fig. 3-19). This sand was deposited in a shallow warm basin, drowning the reefs growing there, but the volume of sediment was not great enough to completely destroy the favorable reef building environment. This accounts for the swift facies changes from clean limestones to limey sandstones and cross-bedded sandstones over short intervals.

2. The Chapman Ridge was followed by deposition of Neuman's (1955) Chota, a final and more restricted occurrence of siliciclastics followed by sea level changes and smaller pulses of siliciclastics of the Sevier and a final drowning of the basin in Bays siltstones and sandstones. Perhaps enough terrestrial iron-bearing clays came in with the Bays and to some extent the Chapman Ridge and were altered to hematite after deposition.
3. It is not physically possible to generate a large enough forebulge to erode 1500 m (5000 ft) of sediment and a deep enough backbulge to accept the 1800 m (6000 ft) of Tellico-Sevier basin sediment. Because all ages of clasts (Middle-Ordovician to basement) are being deposited simultaneously, a barrier of deformed rock that exposes many ages simultaneously would be best. The barrier to westward transport of Taconic arc-derived sediments was likely highlands formed from Lower Ordovician to basement, rift-drift and platform rocks faulted and deformed within a foreland basin (Fig. 3-20,3-21).

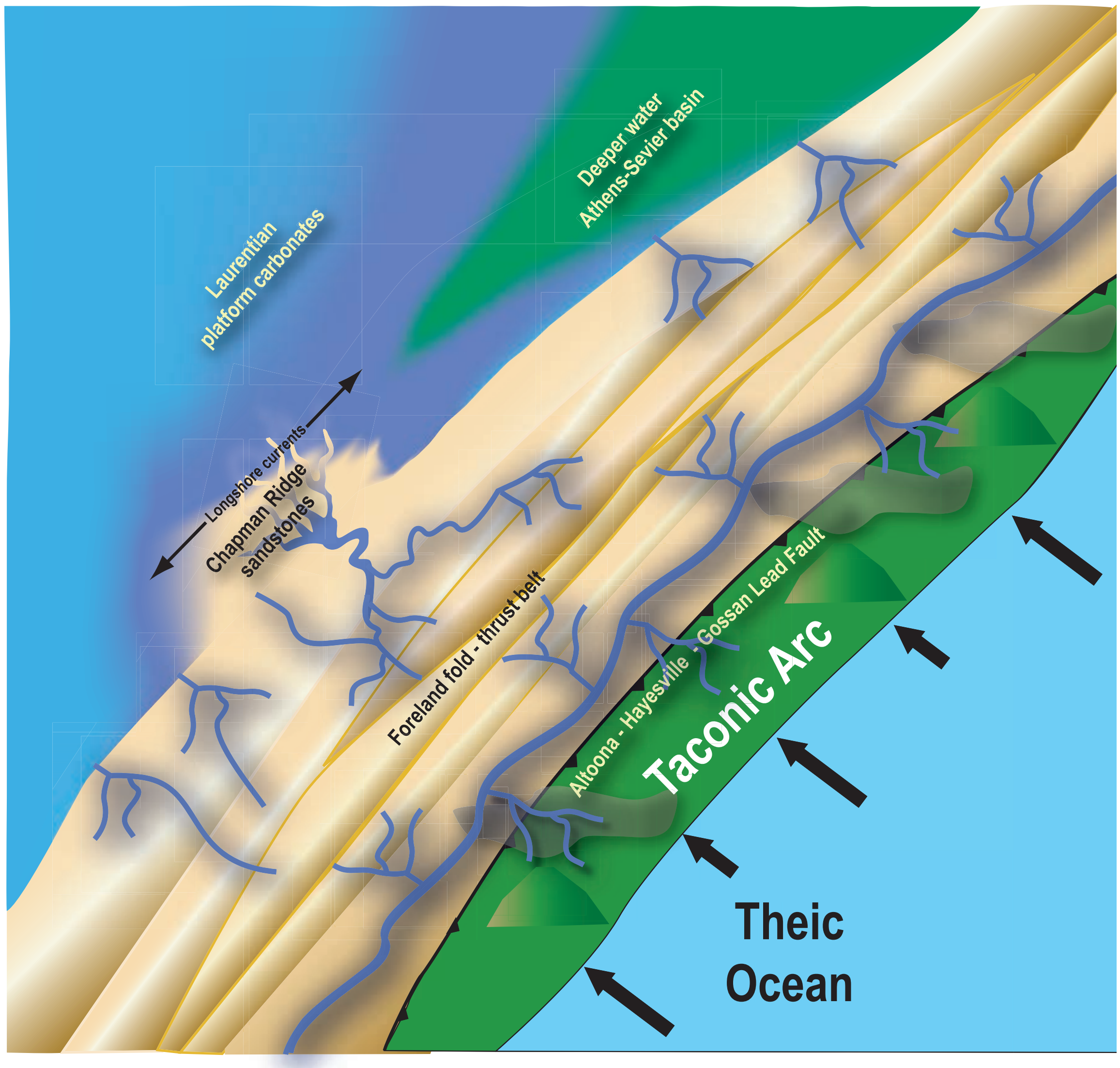


Figure 3-19. Model for the tectonic and depositional setting at time of Chapman Ridge sedimention. Taconic arc may not be as close as shown and may also be striking obliquely, creating the basin here before the main Taconic foredeep further north.

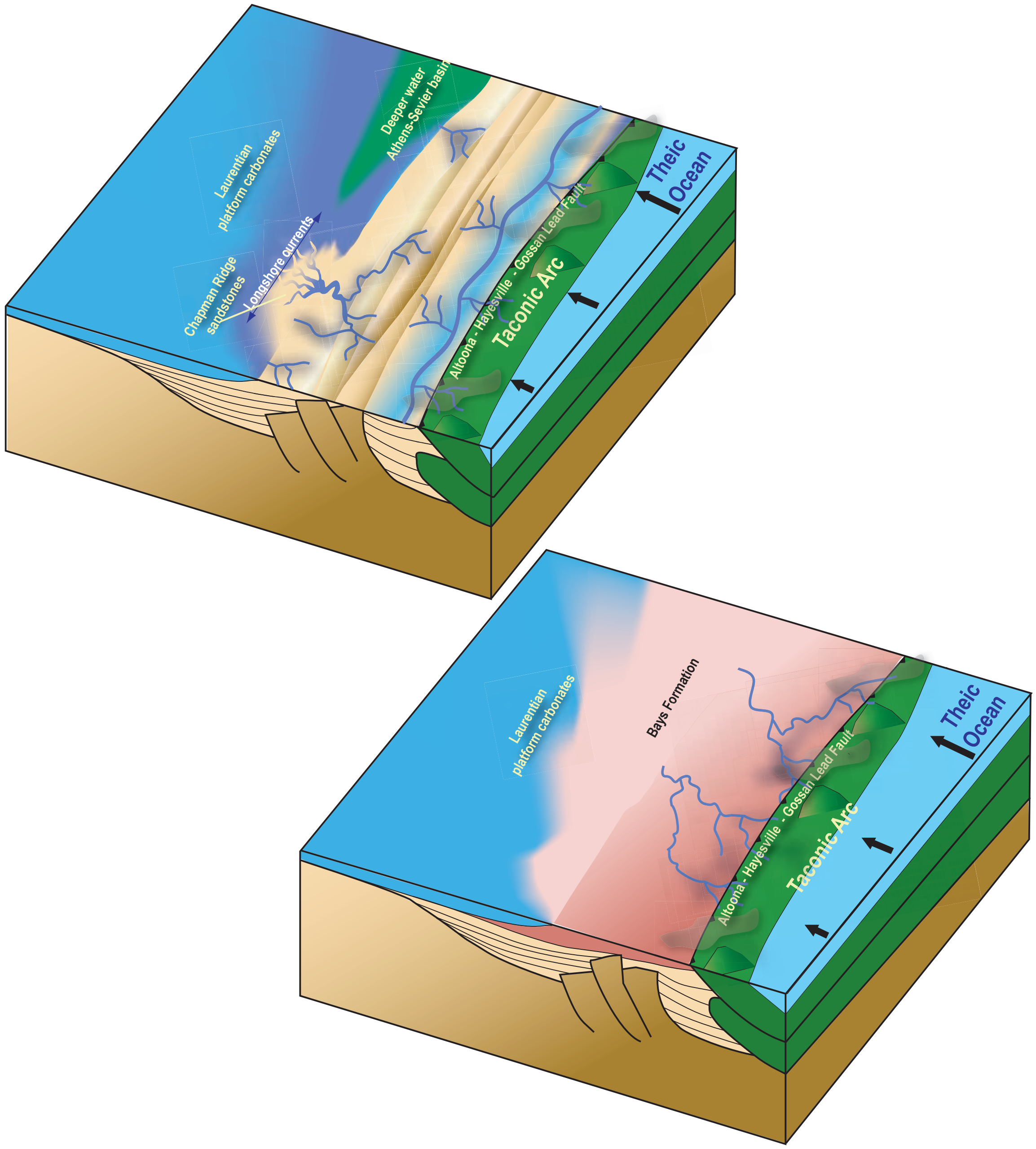


Figure 3-20. Block diagram showing tectonic and depositional setting at time of Chapman Ridge sedimention using complex model of basin formation (Ricci-Lucchi, 1986). Later deposition and continued collisional closure could bury the uplifted platform sediments, drowning the barrier and spilling Bays across what remained of the Sevier basin.

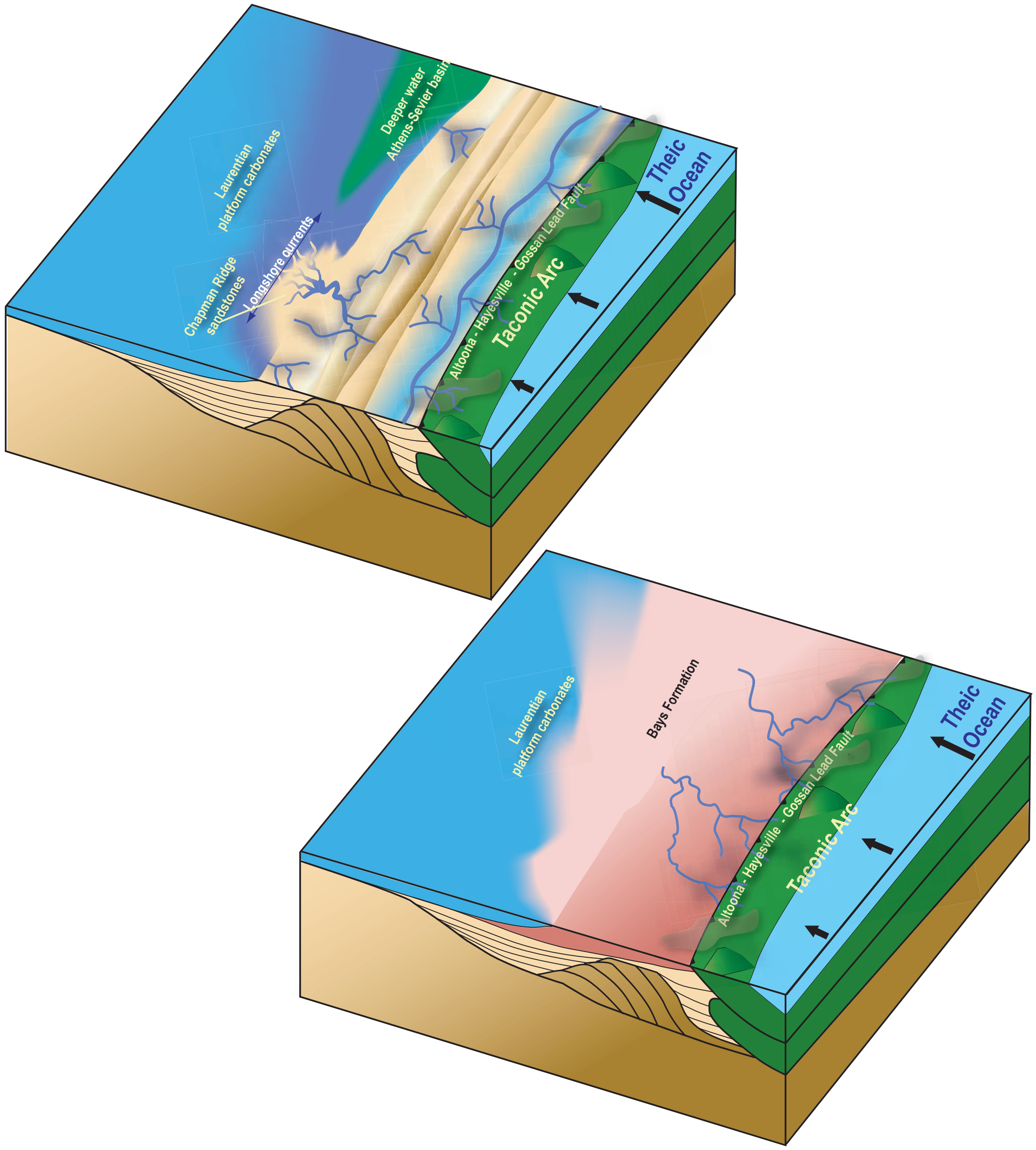


Figure 3-21. Alternate block diagram showing tectonic and depositional setting at time of Chapman Ridge sedimention using foreland fold-thrust belt model of basin formation.

CHAPTER 4

STRUCTURAL GEOLOGY

Regional Overview

The Valley and Ridge of East Tennessee (ETN) consists of Cambrian to Mississippian age rocks brittlely deformed in the Pennsylvanian-Permian Alleghanian FTB during the collision of Laurentia and Gondwana and the formation of Pangea. The Valley and Ridge in ETN is bounded to the west by the Pine Mountain, Cumberland Plateau, and Sequatchie Valley thrusts and to the east by the Great Smoky fault and associated splays (Fig. 4-1).

Deformation in the FTB proceeded as thin-skinned non-basement involved folding and faulting (Rodgers 1964, 1970; Chapple, 1978). The lack of basement involvement in the southern Appalachian FTB suggested by Rich's (1934) work on the Pine Mountain block was later substantiated by Harris (1970), Rodgers (1970), Harris and Milici (1977), Roeder et al. (1978), Woodward and Gray (1985), Hatcher et al. (1987), and Mitra (1988) based on thrust geometries, well data, seismic reflection data, and surface data. These studies are consistent with the Chapple (1978) and Davis et al. (1983) models of thrust behavior as relatively low angle thrust faults above a shallowly dipping basal decollement. Although basement has not traditionally been thought to be actively involved in Alleghanian deformation in ETN, submaster decollement Iapetan rift-related basement faults do exist beneath the FTB (Woodward and Gray, 1985; Mitra, 1988; Costain et al; 1989; Hatcher et al., 1994) and recent studies (Thomas, 1986, 2001; Tavernier, 2002) indicate these faults may have a greater effect on Valley and Ridge deformation influencing the location of ramps from the basal detachment.

Alleghanian faulting generally occurred in sequence from east to west with some local out-of-sequence and opposite vergent faults (Woodward and Gray, 1985; Hatcher et al., 2001; Whisner and Hatcher, 2003) breaking the FTB in ETN into 10 imbricate thrust

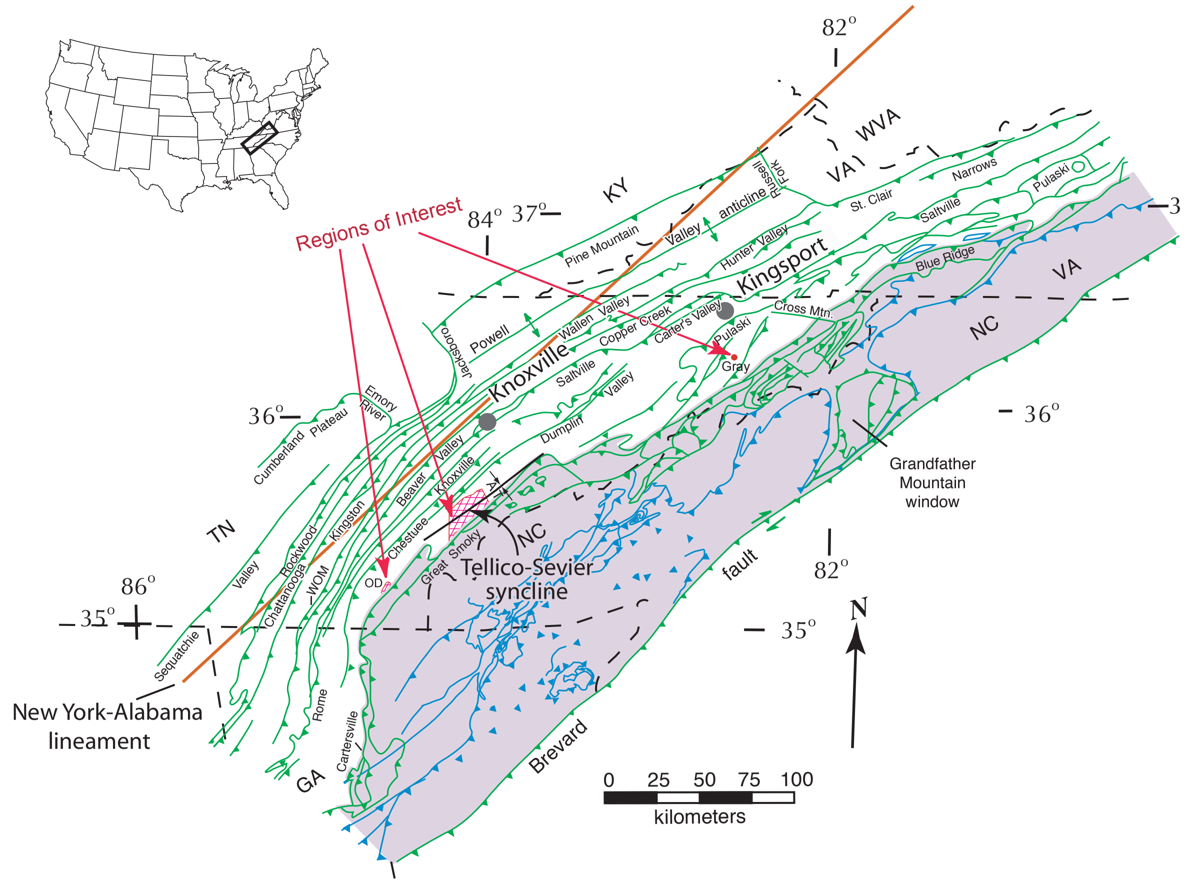


Figure 4-1. Major faults in the Valley and Ridge in East Tennessee and surrounding states showing location of three primary study areas. WOM= Whiteoak Mountain, OD= Oswald Dome. Lavender shading denotes Blue Ridge province. Modified from Hatcher et al., 1990.

sheets at the latitude of Knoxville (Rodgers, 1953; Hardeman et al., 1966; Geiser, 1988) (Fig. 4-1). The sheets are cored by structural-lithic units consisting of Maynardville, Knox Group, and Chickamauga Group carbonates to the north and west and clastics to the south and east, and move on basal detachments within the Rome shales, sometimes utilizing higher detachments along weak structural-lithic units such as the Conasauga, Chickamauga, and Chattanooga shales. Macroscopic deformation is exhibited not only as faults, but also as large folds evident in several thrust sheets throughout the Valley and Ridge (Fig. 4-2). Most map-scale folds are synclines in the footwalls of major faults, as most hanging-wall anticlines have been removed by erosion. Internal microscopic deformation and pressure solution contributes little to overall shortening (<10%) (Lutz, 1987). The combination of folding and faulting has accumulated over 250 km of shortening (at least 50% shortening in some areas) (Roeder et al. et al., 1978; Wiltschko et al., 1985; Woodward and Gray, 1985; Kilsdonk and Wiltschko, 1988; Hatcher, 1989).

It is possible that deformation related to Triassic rifting and opening of the Atlantic Ocean may have overprinted Alleghanian Valley and Ridge deformation. Potential examples of the overprint are the Cross Mountain fault (Figs. 4-1 and 4-3) and other east/southeast-west/northwest trending strike-slip faults in northeast Tennessee near Johnson City (King, 1944; King and Ferguson, 1960; Pugh, 1966), and joints and lineaments (possible faults) traceable in the Blue Ridge of North Carolina and Tennessee (Clark, 1989; Lane, 1997).

Previous Geologic Mapping

Many geologists have produced bedrock geologic maps that include parts of the study area. Hardeman et al. (1966) 1:250,000-scale geologic map of Tennessee contains the most current compilation and covers a large area but is understandably generalized due to its small scale and large scope. Geologic mapping at 1:24,000 is common, although no single mapper has covered more than a portion of a 7.5-minute quadrangle

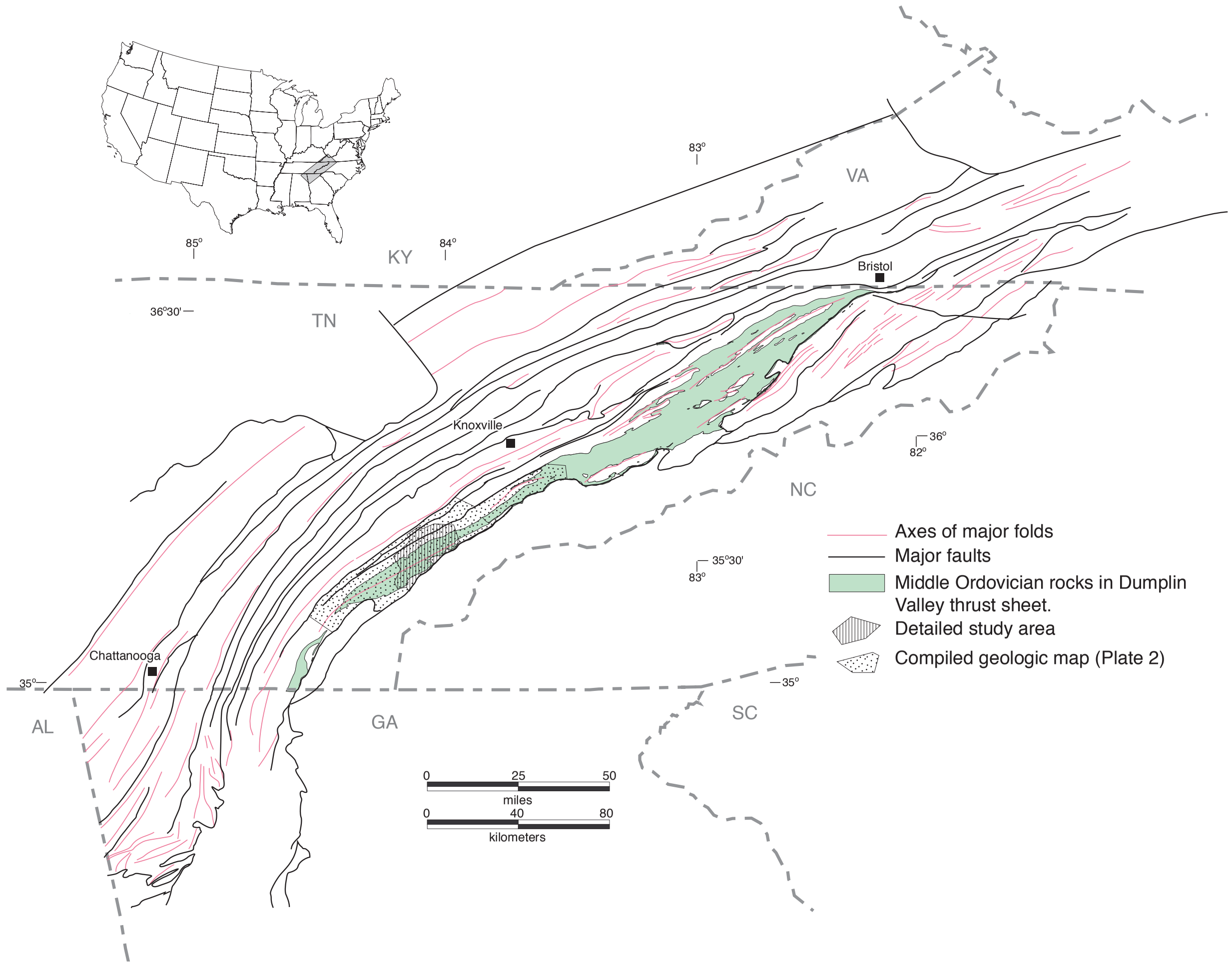


Figure 4-2. Major faults, and fold axes, and location of the Middle Ordovician rocks of the Tellico-Sevier syncline and related rocks in the Dumplin Valley thrust sheet in the Valley and Ridge of East Tennessee, Georgia, and Virginia.

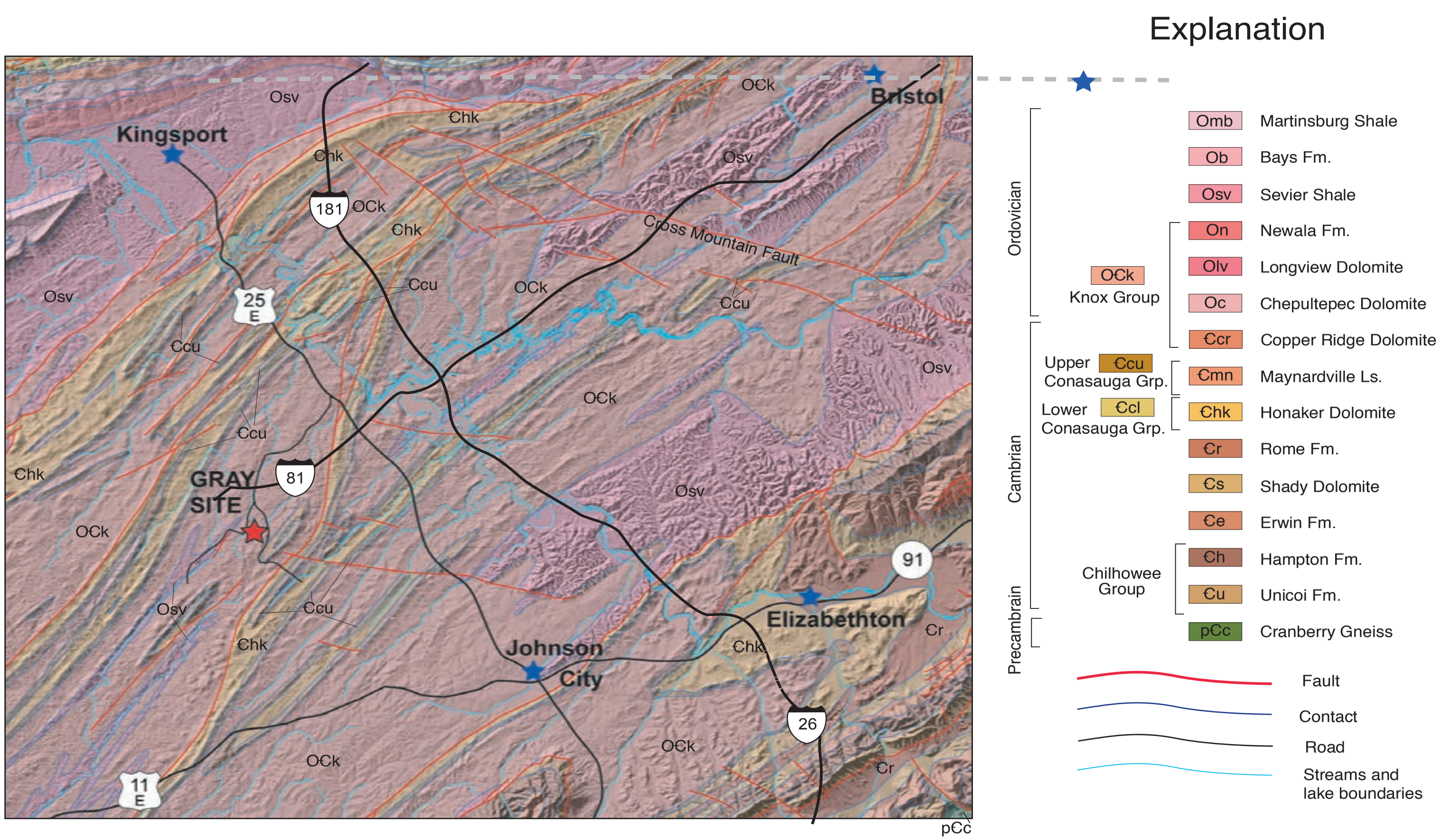


Figure 4-3. Cross Mountain fault and other east/northeast-west/southwest striking faults near Kingsport, Tennessee. East/northeast-west/southwest trending faults are not as well mapped further south in the Valley and Ridge or the Blue Ridge. Geology modified from Hardeman et al. (1966), Topography from 1:24,000-scale 30m DEMs from USGS EROS data center.

in the study area (Fig. 4-4). Neuman (1955) mapped along the Little Tennessee River concentrating on Middle stratigraphy. Neuman (1955) also proposed a stratigraphic nomenclature for this region that differed from his contemporaries' usage (Rodgers, 1953) and was not used in the state map compilation (Hardeman et al., 1966). A modified version of Neuman's (1955) stratigraphy is presented here. Wiener (unpublished) primarily worked in the hanging wall of the Great Smoky fault but mapped some of the Valley and Ridge including the southeastern edge of the mapped area. McKinney (1964) and Martin (1997) mapped just to the south of the study area around Tellico Plains, TN, focusing mainly on bedrock geology. Biery (1968) mapped a portion of the study area at 1:24,000 focusing on Middle Ordovician to Mississippian age rocks in the footwall of the Great Smoky fault. Kashfi (1971) revisited Neuman's stratigraphy, mapping parts of the Mount Vernon, Rafter, and Tellico Plains 1:24,000-scale quadrangles as part of Dr. Kenneth Walker's Sevier-Blountian basin study. Mapping by Robey (2000), Thigpen (2002), Heath (2003), and myself overlapped in time, allowing standardization of mapped geologic units. Robey (2000), Thigpen (2002), and Heath (2003) mapped the hinge and part of the body of the syncline at 1:24,000 just southwest of the area mapped by myself (Fig. 4-4). I mapped the portion of the syncline south of Vonore, Tennessee, along the Little Tennessee and Tellico Rivers using both foot and canoe traverses along with remote sensing techniques to try and pinpoint unusual deformation in the field area (Plate I and Fig. 4-5). My detailed geologic map was combined with the work of previous researchers (Keith, 1896; Rodgers, 1953; Neuman, 1955; Neuman and Wilson, 1960; King, 1964; McKinney, 1964; Hardeman et al., 1966; Biery, 1968; Kashfi, 1971; Martin, 1997; Robey, 2000; Thigpen, 2002; Heath 2003; Wiener, unpublished) in an attempt to resolve the geology of the Tellico-Sevier syncline in greater detail (1:24,000) than the state geologic map (1:250,000) as well as correlate the units in a unified stratigraphic framework (Chapter 2) in ETN (Fig. 4-6, Plate II).

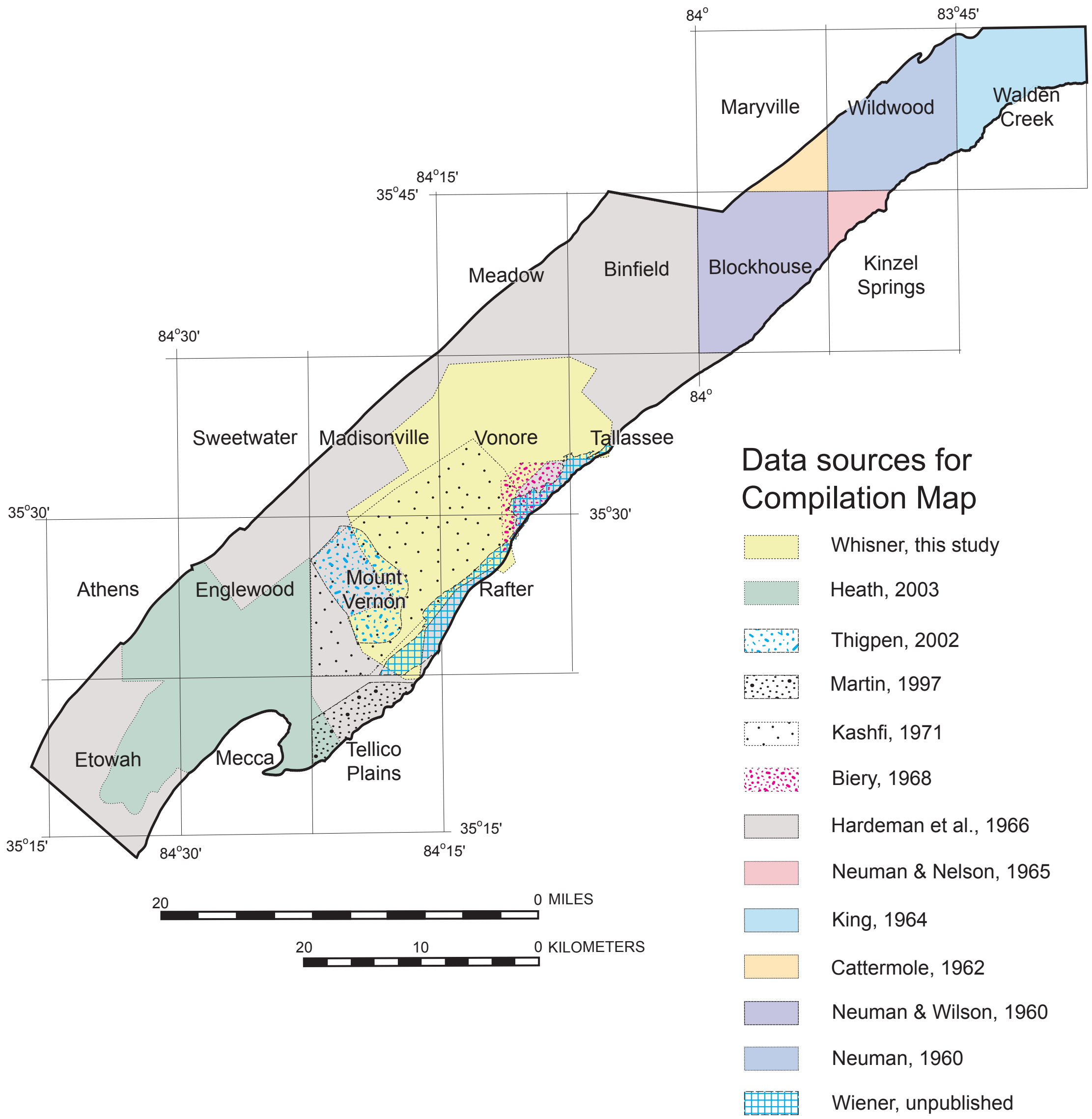


Figure 4-4. Geologic mapping of the southwestern Tellico-Sevier syncline.

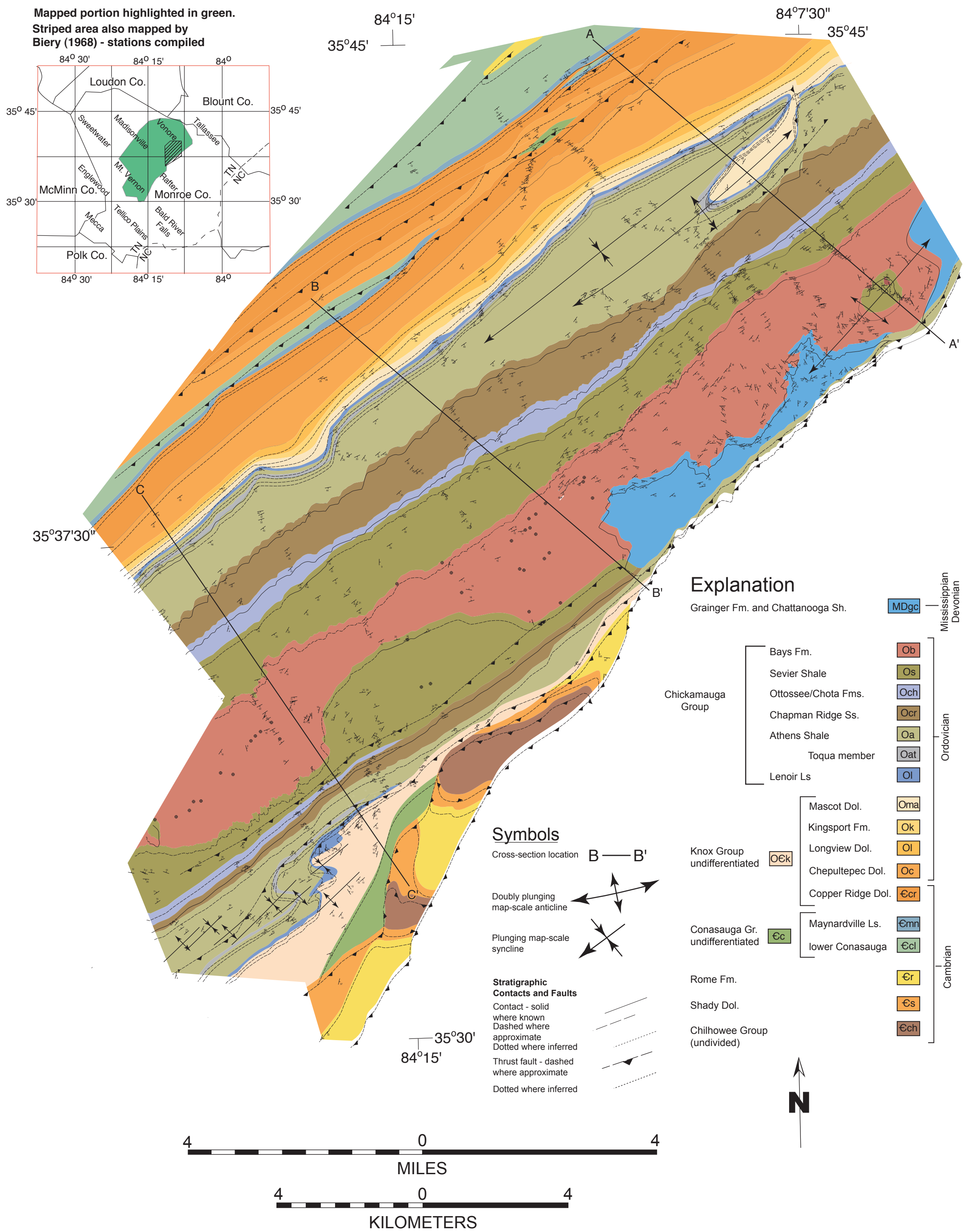


Figure 4-5. Geologic map of the field area with location of cross section lines.

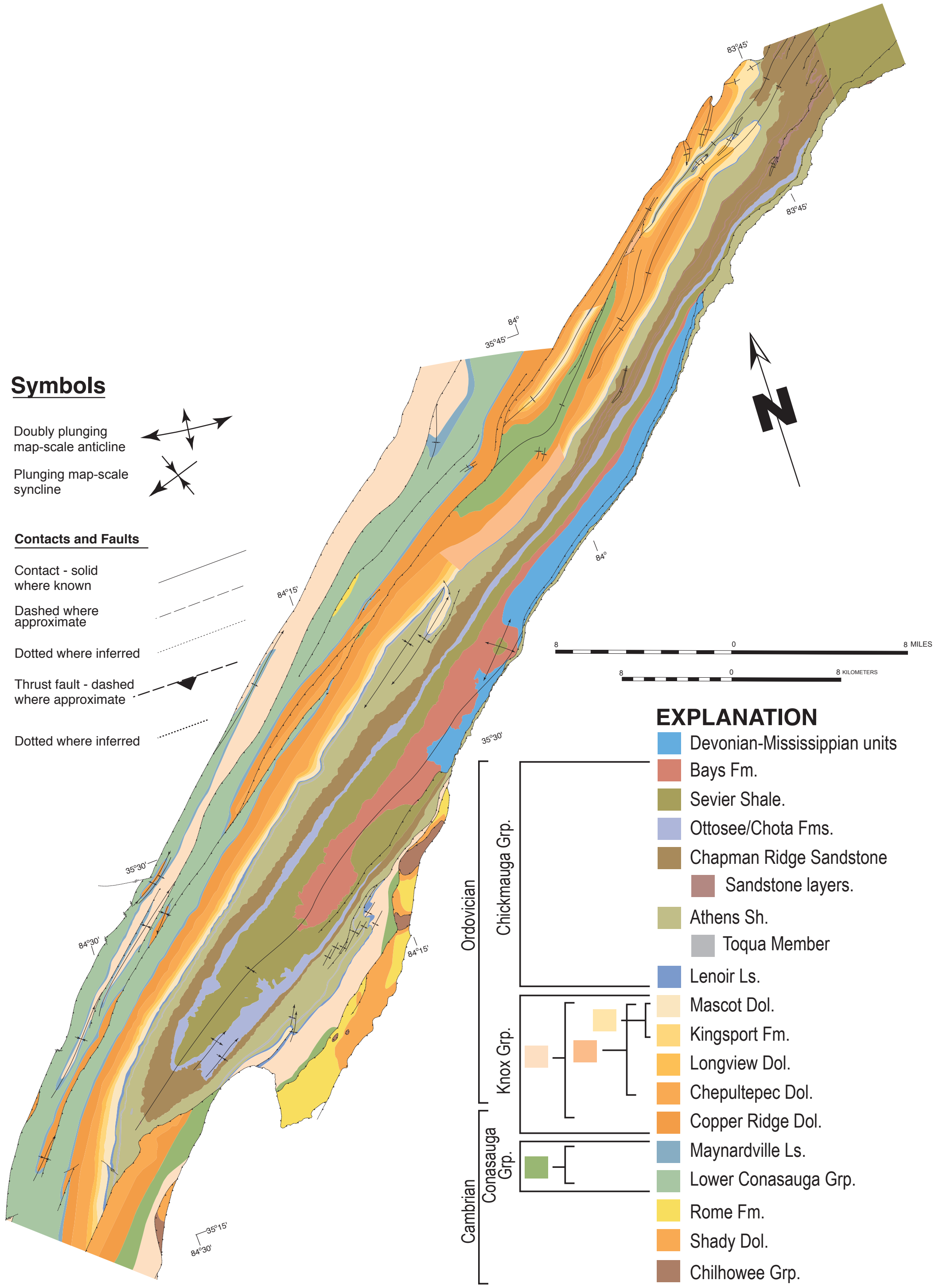


Figure 4-6. Geologic map of the Tellico-Sevier syncline between Etowah, Tennessee and the north end of Chilhowee Mountain compiled from this author's and previous 1:24,000 scale geologic mapping as detailed in Figure 4-4.

Regional Structures

Tellico-Sevier Syncline

The dominant structure in the study area is the Tellico-Sevier syncline, an upright to overturned, syncline comprised of units from the Cambrian Rome Formation. to the Mississippian Grainger. The syncline extends from south of Etowah, Tennessee, to DuPont, Tennessee to the north, paralleling the Great Smoky fault as it is progressively overridden by the Guess Creek fault and rocks of the Blue Ridge to the north. Only the western limb is exposed in the northern portion (Fig. 4-6). Just north of Chilhowee Mountain in Sevier County, complex folding and faulting in the Sevier shale suggest the syncline no longer exists and has been replaced by more complex structure (Fig. 4-2).

The Tellico-Sevier syncline is bordered to the southeast by the Blue Ridge/Great Smoky fault and associated footwall splays. The syncline technically lies in the greater Saltville thrust sheet primarily in the Dumplin Valley. To the south, the Saltville sheet is broken into smaller thrust sheets: the Knoxville sheet, and the Chestuee/Dumplin Valley/Wildwood sheet; the Tellico-Sevier syncline lies in the latter thrust sheet. The syncline is the primary record of the Middle Ordovician Blount-Sevier basin, commonly assumed to be the foreland basin associated with island arc collision with the southern Laurentian margin during the Taconic orogeny (Benedict and Walker, 1978; Walker et al., 1983; Drake et al. 1989). It is the largest and best preserved of several Middle-Ordovician cored footwall synclines in the Valley and Ridge.

Blue Ridge/Great Smoky Fault

The Blue Ridge/Great Smoky fault system, marking the easternmost edge of the mapped area, brings up Lower Cambrian Chilhowee and un to low-grade metamorphosed Walden Creek Group rocks and older rift-related rocks as part of a large composite crystalline thrust sheet riding over the deformed, but unmetamorphosed, rocks of the Valley and Ridge. The Great Smoky fault is a low-angle thrust fault through which duplexes of Knox Group rocks are exposed in simple windows in the Blue Ridge to the east (i.e., Cades Cove, Tuckaleechee Cove, etc.; [Hatcher et al., 1994]).

Chestuee/Dumplin Valley/Wildwood Thrust Sheet

The Chestuee/Dumplin Valley/Wildwood thrust sheet is the easternmost thrust sheet exposing a nearly complete stratigraphic section west of the Great Smoky fault (Hardeman, 1966). The southern tip of the Tellico-Sevier syncline lies in the Chestuee thrust sheet. Between Etowah and Englewood, Tennessee, the Dumplin Valley and Wildwood faults, along with minor splays, fold and fault the older units (Conasauga Group, Knox Group) in the northwest limb of the syncline in the hanging wall of the Chestuee fault.

Study Area

The Tellico-Sevier Syncline

The northwest limb of the Tellico-Sevier syncline strikes 055 and has a moderate dip to the southeast at about 45 degrees and flattens to the southeast. This limb is broken by two regional but small displacement thrust faults (Wildwood and Dumplin Valley, Figs. 4-2, 4-5, and 4-6) that thrust Nolichucky Shale (Conasauga Group) over Knox Group. The southeastern limb strikes 060 and is flat to shallowly dipping in the youngest units (Grainger and Bays Fms.), but to the southwest becomes steep to overturned closer to both the Guess Creek fault and the Great Smoky fault, which brings Chilhowee and Walden Creek Group rocks over the limb. Units from the Sevier Shale down to Conasauga shale are exposed in the southeastern limb of the syncline in the southern portion of the syncline. North of Ballplay Creek (Plate I), however, this limb is overridden by the Guess Creek fault and only the Grainger and a thin faulted sliver of Athens Shale are exposed.

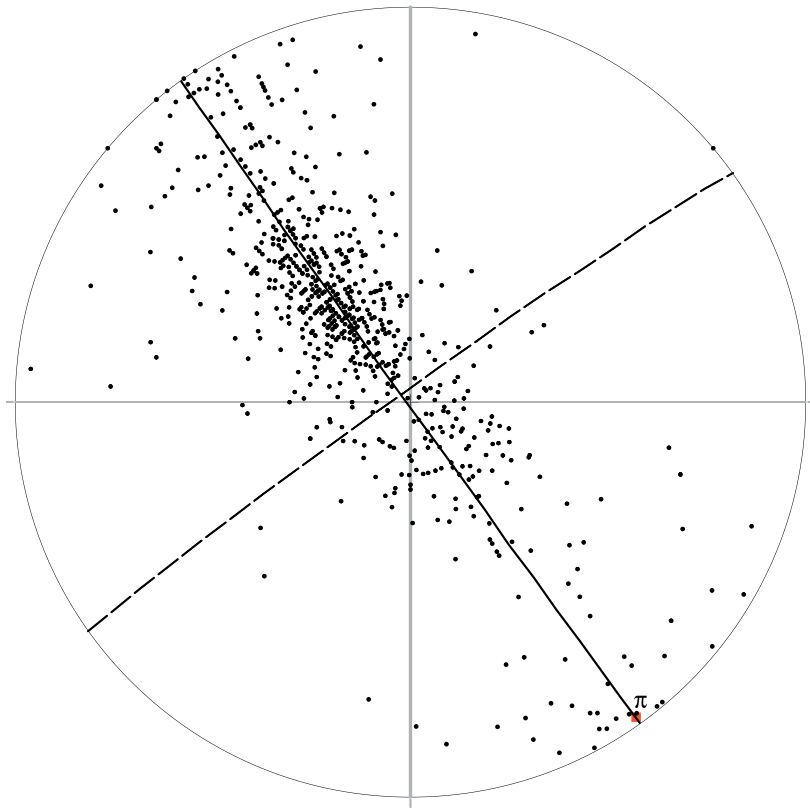
The axial trace of the Tellico-Sevier syncline trends approximately 054, and plunges 1° NE, as can be seen in the stereonet of dip data (Fig. 4-7) and the detailed geologic map (Fig. 4-5, Plate I). Heath (2003) estimated a 3° plunge at the southwest end of the syncline.

Map-Scale Secondary Structures

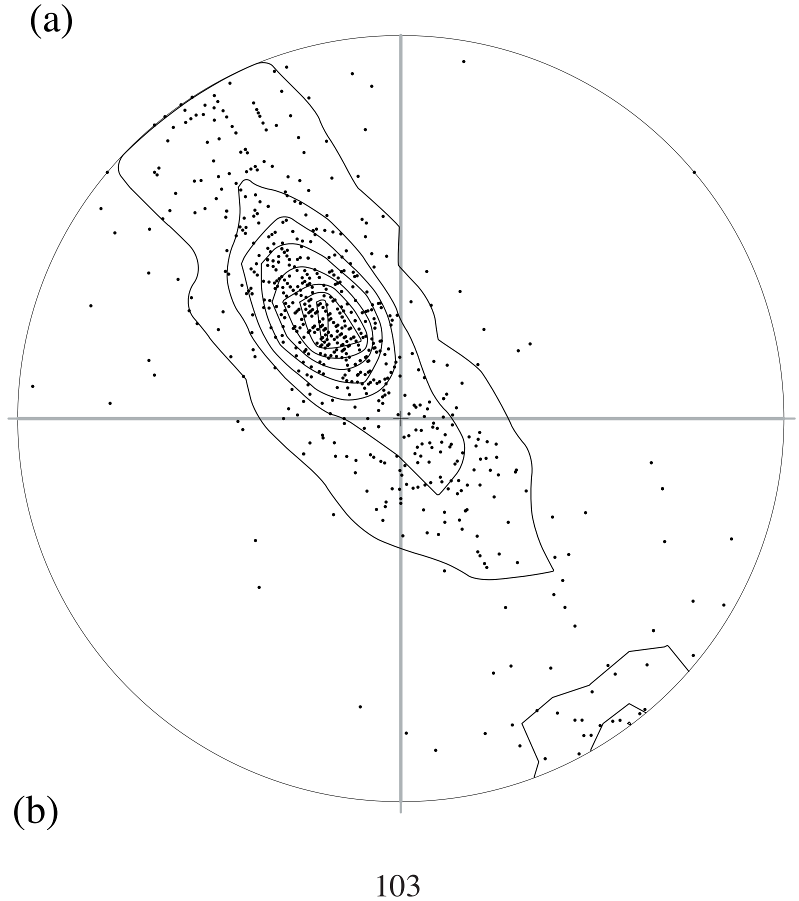
Numerous map-scale smaller faults and folds modify the major Tellico-Sevier syncline. One such structure is a parasitic anticline-syncline pair in the Vonore and Tallassee 7.5-minute quadrangles, here called the Kyker Bottoms folds (Figs. 4-5 and 4-8, Plate I). This fold pair is upright, relatively tight, parallel, and gently plunging (Figs. 4-8 and 4-9). The fold pair deforms Upper Knox (Mascot) through Athens Shale in the northwest limb of the syncline, but is most easily observed in outcrops of Lenoir Limestone and Toqua Sandstone. The fold pair is confined to the Athens-Mascot, as the Chapman Ridge Sandstone appears to be only slightly deformed (shallower than average dips) near the nose of the syncline. The deformation manifests itself as an isolated deviation in strike orientation from the general trend (050) to 070. The Kyker Bottoms anticline is oriented 227, 6 (Fig. 4-9), and the syncline is oriented 233, 1 (Fig. 4-9). The folds plunge opposite to those of the larger Tellico-Sevier syncline (Fig. 4-7) but are at a very shallow angle.

In the southeastern limb of the anticline, the Lenoir Limestone forms a subdued ridge that terminates as southwest Ninemile Creek, suggesting a northeast trending fault cuts the ridge. The termination could also result from a doubly plunging anticline that has been breached along its northern hinge. The Lenoir outcrop pattern is unusual because the northwest limb of the syncline and the southeast limb of the anticline appear continuous along strike near the hinge of the syncline. The outcrop width of the Athens Shale may indicate the areal extent of the fold pair; the outcrop width nearly triples down plunge (southwest) and this increased width continues southwest across the Tellico Reservoir to the junction of Notchy Creek with Tellico Reservoir (Figs. 4-5 and 4-8,

Figure 4-7. Lower hemisphere, equal area stereographic projection of 749 poles to bedding in the Tellico-Sevier syncline. Shallow plunge of the syncline is apparent as is upright axial surface. (a) Scatter plot of poles to bedding with cylindrical best-fit great circle. Filled red square is the π-axis to the great circle, and best estimate of the fold axial orientation of the syncline, 54, 1. Dashed line represents axial surface orientation, 234, 88. (b) The same data set contoured using with Kamb (1959) 4 sigma contours. Note the strong concentration of dips at ~50˚ southeast. This contrasts with to the relative dearth of data points with a northwesterly dip expected from the southeastern limb (Fig. 4-5). Plots made using StereoWin v. 1.2.0 by R. W. Allmendinger (2002, Cornell University).



(a)



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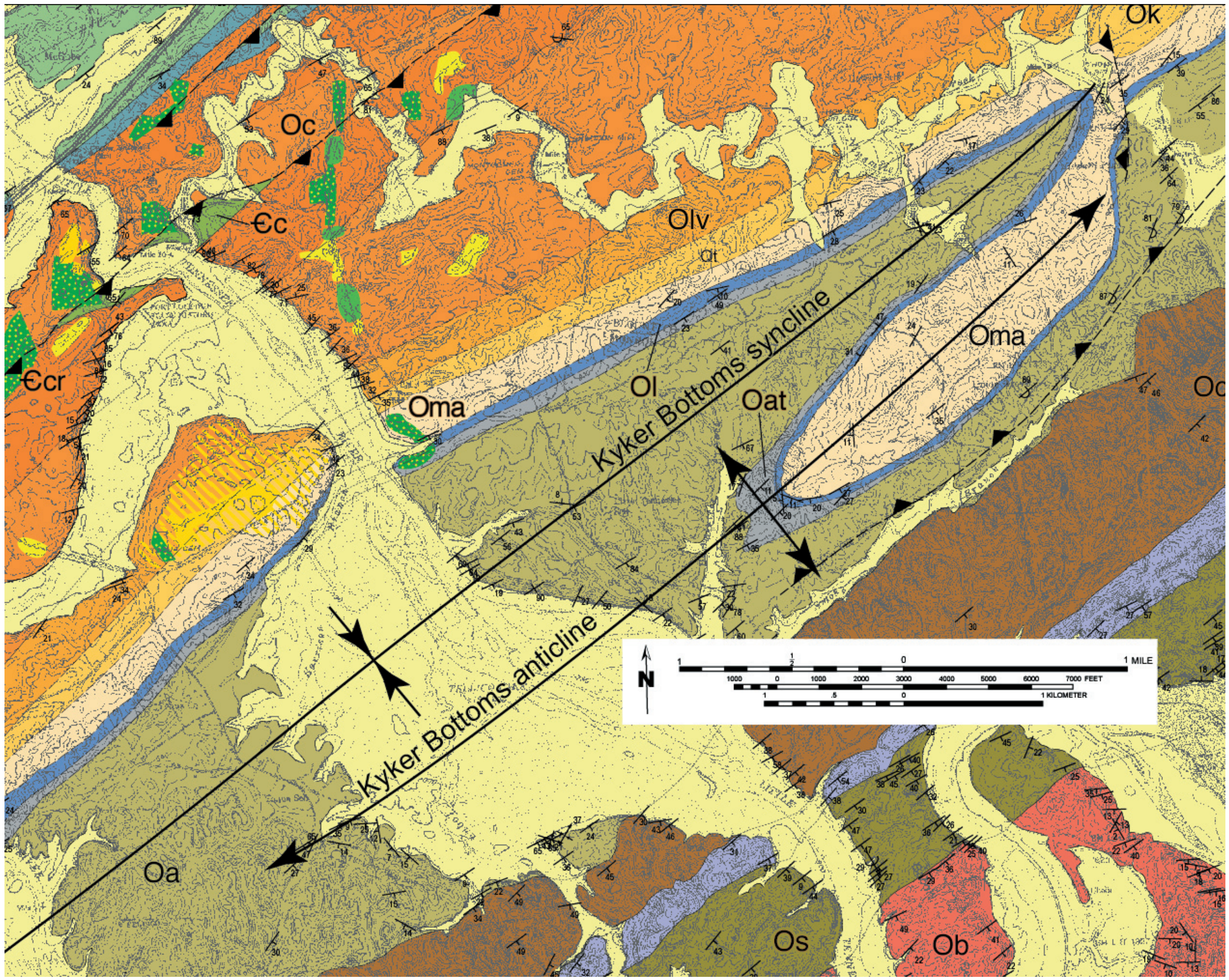

Figure 4-8. Geology of parts of the Vonore and Tallassee quads showing the Kyker Bottoms syncline and anticline cored by Mascot Dolomite. See Figure 4-5 for explanation of map symbols.

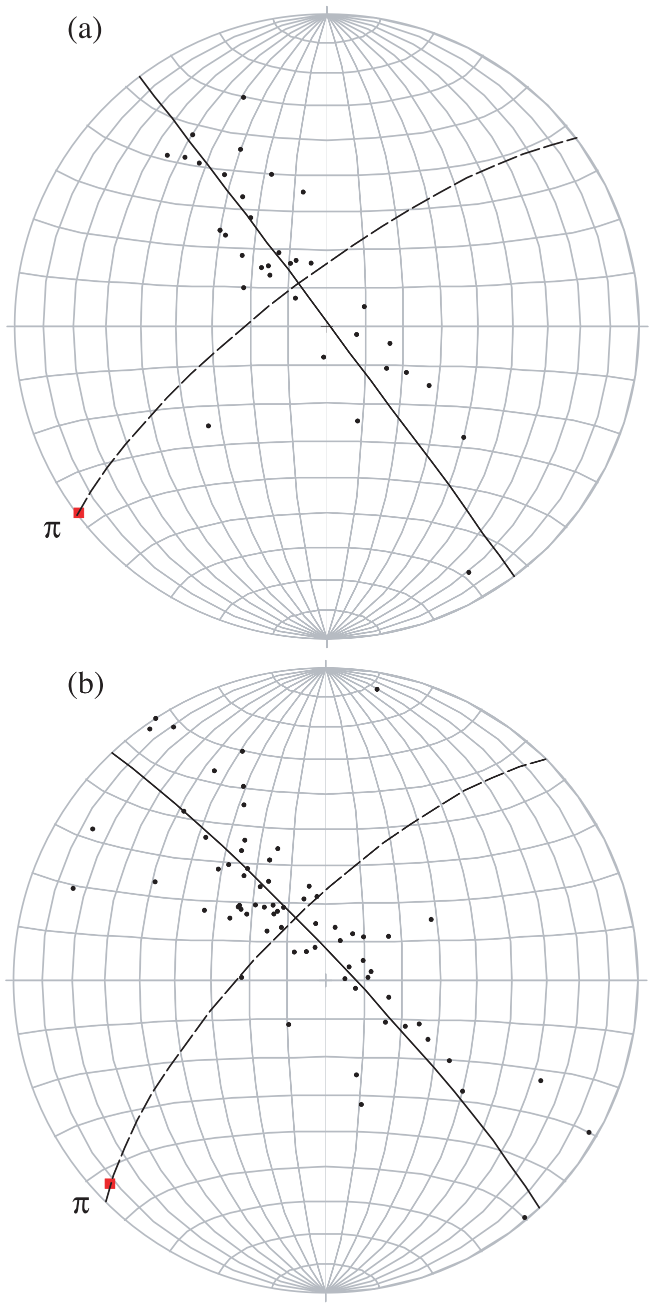

Figure 4-9. Lower hemisphere, equal area stereographic projection of poles to bedding in the Kyker Bottoms syncline (n=35) and anticline (n=75). Solid lines are cylindrical best-fit great circles (p circles) to poles to bedding. Filled red squares are p-axes to the great circles, and best estimates of fold axis orientations. Dashed lines represent axial surfaces. (a) Scatter plot for Kyker Bottoms syncline. Fold (π) axis orientation 233, 1; axial surface orientation 233, 83. (b) Scatter plot for Kyker Bottoms anticline. Fold (π) axis orientation: 227, 6; axial surface orientation 225, 73. Plots made using StereoWin v. 1.2.0 by R. W. Allmendinger, 2002, Cornell University.

Plate I). The Athens also thickens northeastward, which could be a continuation of the folds (if doubly plunging) along strike to the northeast. Steep to overturned dips and narrow outcrop width in the Athens Shale on the southeast limb of the anticline suggest another fault may thin the Athens, but there is not enough exposure to confirm this.

Another small mappable structure is a dome of Sevier Shale with Bays Formation sandstone preserved on both the crest and limbs (Figs. 4-5 and 4-10, Plate I). The dome is bisected by the Little Tennessee River near Pumpkin Center. The cap of Bays sandstone is relatively thin, preserving ≤30 m (100 ft) at most. Dip data reveal a cluster of low dips and random strike orientations (Fig. 4-11) indicating a relatively symmetrical dome. This may indicate the presence of a low displacement duplex of limited along strike extent in the lower part of the stratigraphic section. Lack of more extensive exposure of the structure and seismic reflection data make this hypothesis difficult to support. Interestingly, this dome appears along the assumed northwest transport direction just southeast of the Kyker Bottoms structures and fault that thinned the Athens shale.

Kashfi (1971) identified a fault (Hicks fault) thinning the Sevier Shale between of Acorn and Tarriffville, Tennessee (Figs. 4-5 and 4-12, Plate I). The fault likely terminates in an unusually wide outcrop belt of Sevier Shale. South of Laurel Mountain, the Sevier outcrop width narrows again, and steep, overturned Sevier is juxtaposed against nearly flat-lying Bays Formation. I suggest that the Sevier is thinned by another fault, here called the Regan Valley fault, and that deformation is partitioned into a gentle anticline in the wide outcrop belt between the two faults.

Yet another map-scale structure consists of folded Athens shale, Lenoir Limestone, and Knox Group along the Tellico River in the Belltown folds (named here) (Figs. 4-5 and 4-13). Accommodation of deformation changes from folding and faulting to the southwest to simply faulting (Sink fault, [Kashfi, 1971]), which continues to the northeast where it is overridden by the Guess Creek and Great Smoky faults. This fault

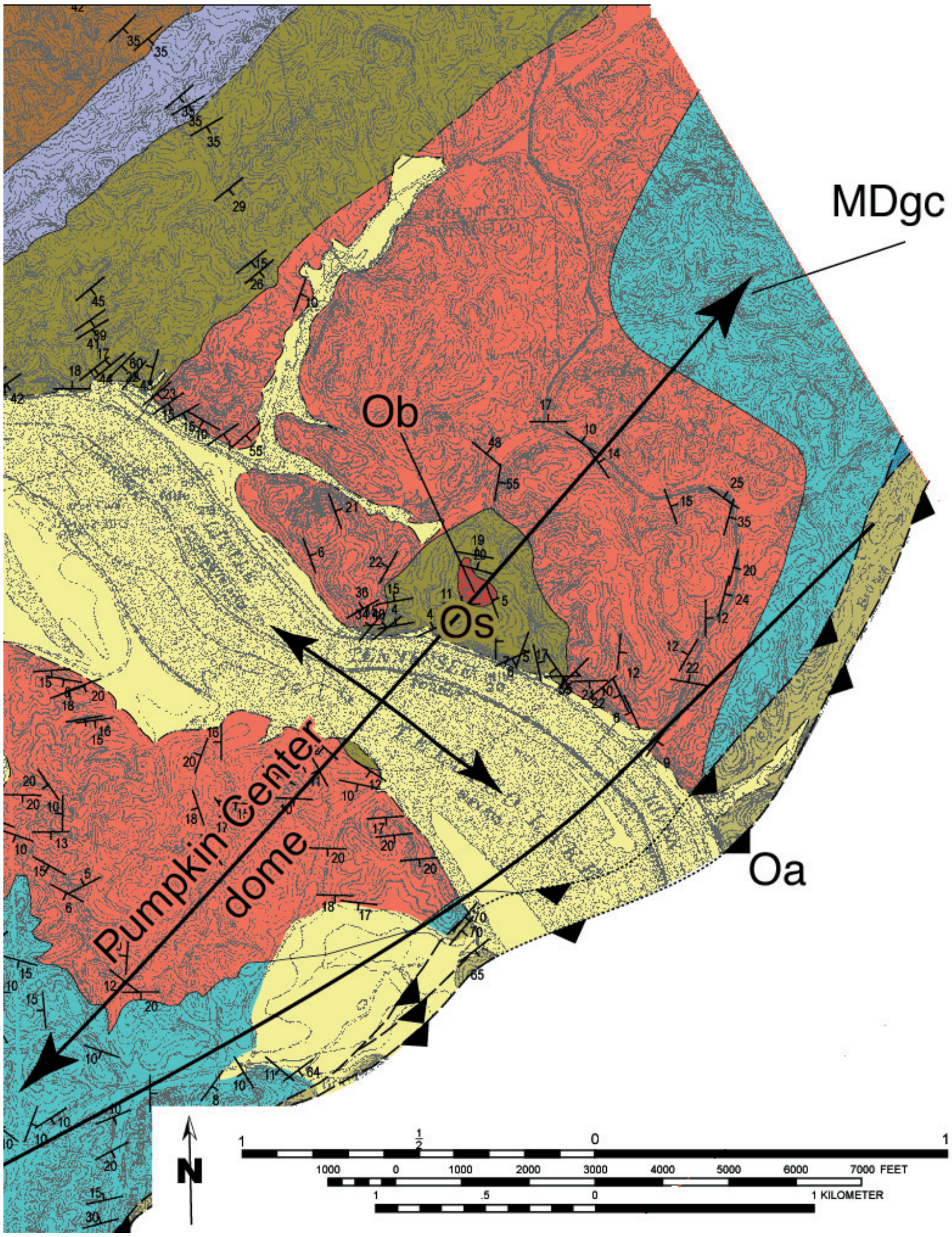

Figure 4-10. Pumpkin Center dome capped by Sevier. See Figure 4-5 for explanation of map symbols.

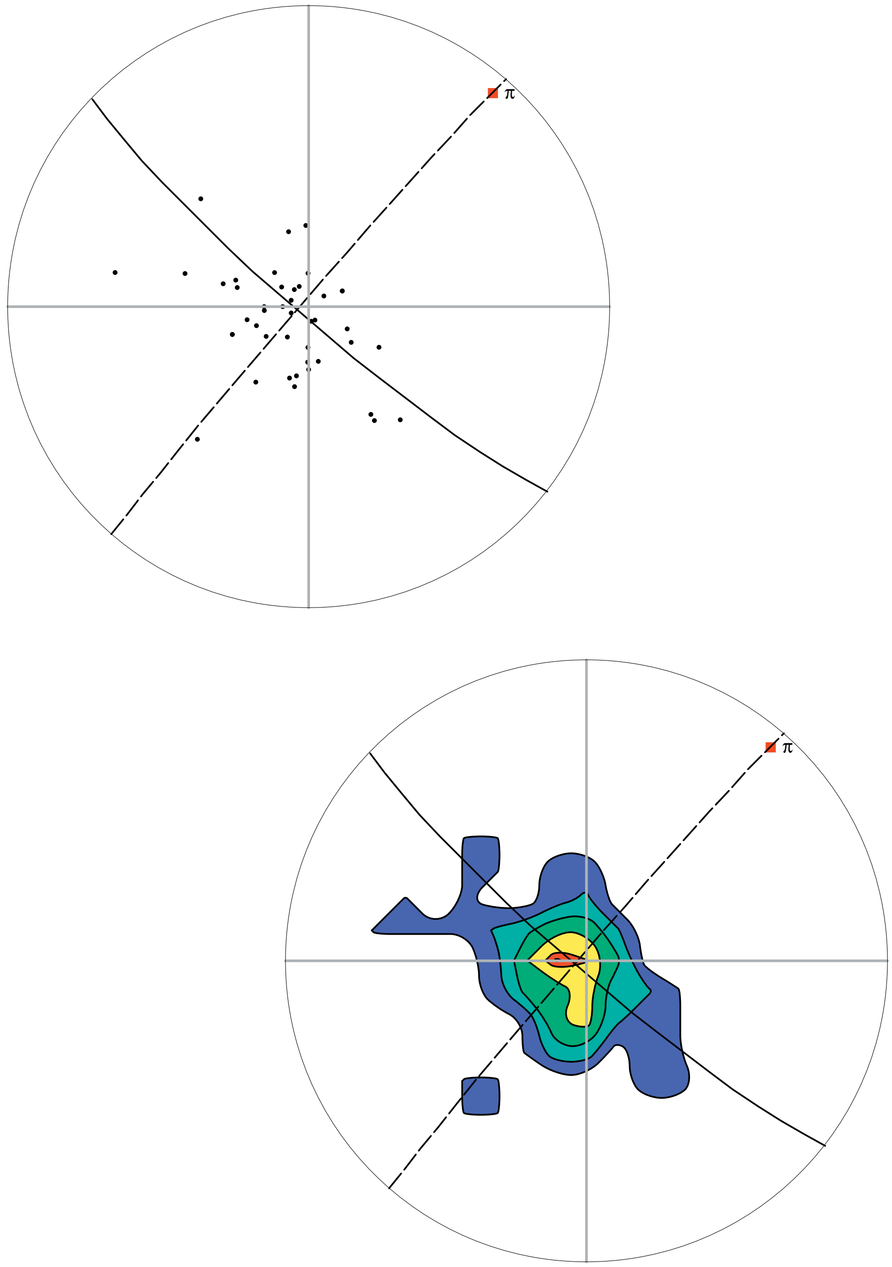

Figure 4-11. Lower hemisphere, equal-area stereographic projection of 44 poles to bedding in the Pumpkin Center dome. Solid line is cylindrical best-fit great circle to poles to bedding. Filled red square is π-pole to the great circle, and best estimate of fold axis orientation: 41, 7. Dashed line represents axial surface: 221, 88. Bullseye on diagram is of 1% area with 4% area density contour interval (red is 16% area density). Plot made using StereoWin v. 1.2.0 by R. W. Allmendinger, 2002, Cornell University.

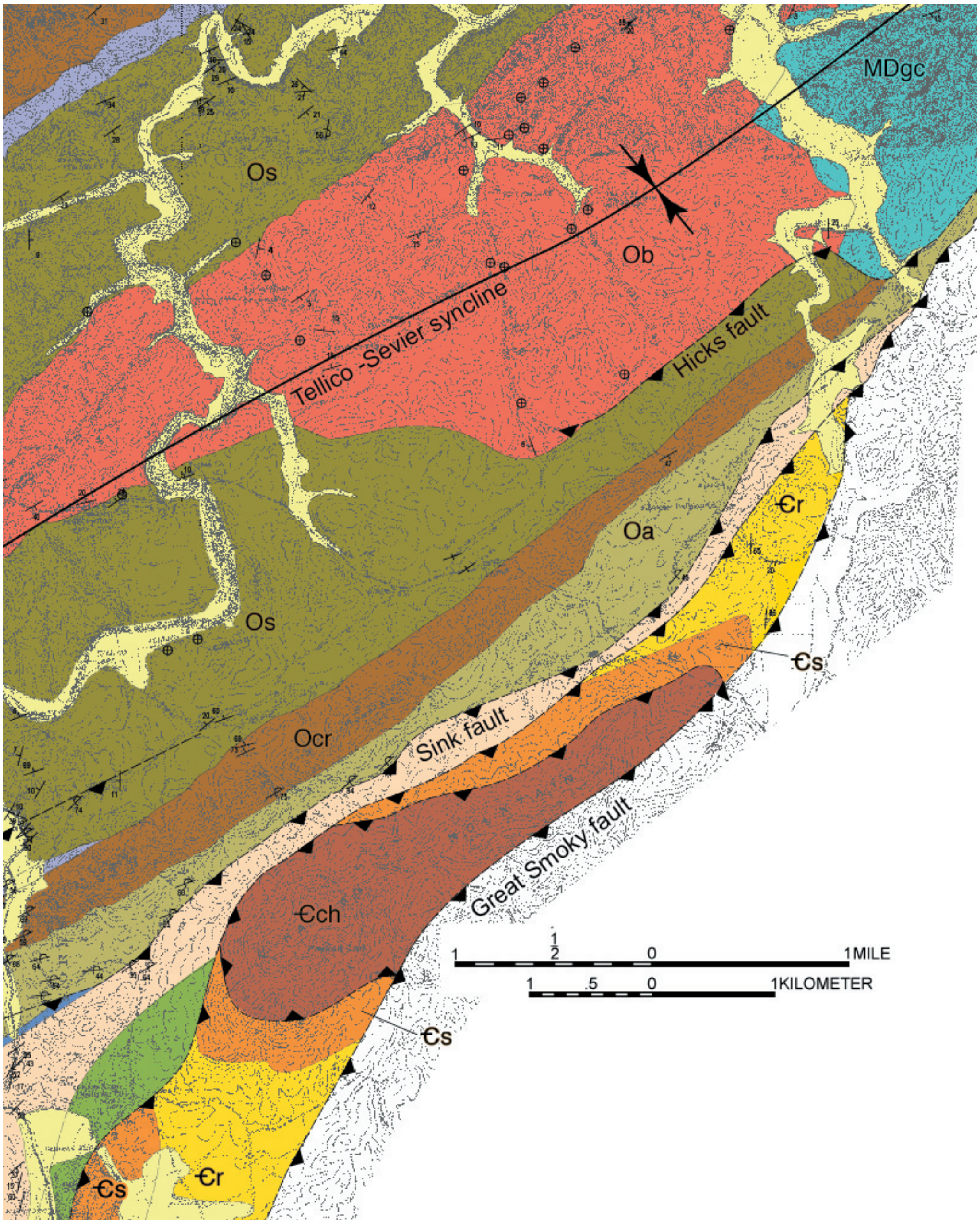

Figure 4-12 Hicks and Sink faults along the southeastern boundary of the area mapped in detail. See Figure 4-5 for explanation of map symbols.

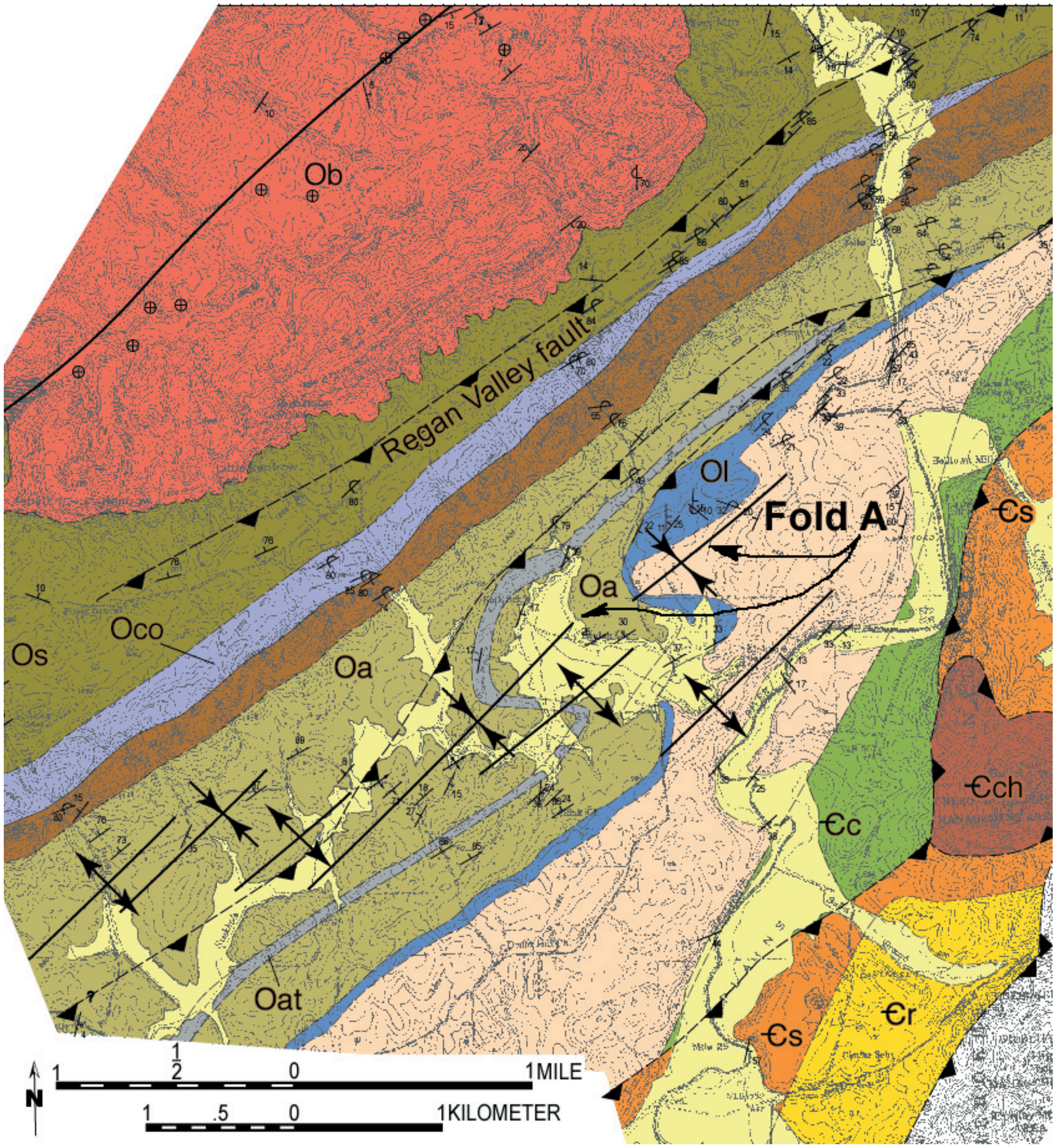

Figure 4-13. Belltown anticline syncline pair. See Figure 4-5 for explanation of map symbols.

duplicates Athens Shale and Toqua Sandstone, and was suggested by Kashfi (1971) to explain an unusually narrow outcrop width of Athens Shale. As the fault trace extends southwest across the Tellico River, it becomes difficult to determine its exact location because the Toqua is poorly exposed and colluvium from the Chilhowee Group rocks on Harlan Mountain obscures units of the Tellico-Sevier syncline. The map pattern of folded Athens-Lenoir-Knox in the hanging wall of the Sink fault (fold A in Fig. 4-13) suggests that these rocks comprise an anticline in a parasitic fold train on the southeast limb of the larger syncline. Strike and dip data, however, including Wiener's unpublished data indicate that fold A (Fig. 4-13) is a synform, and the entire fold train has been inverted. These data point to a complicated deformation history over a very small area. The Sink fault occurs at the same stratigraphic level and along the same trend as Heath's (2003) Conasauga Creek fault to the south (Fig. 4- 6, Plate II). This may indicate the Sink and Conasauga Creek faults are connected, but a lack of data northwest of Tellico Plains, Tennessee between the two faults makes this hard to confirm.

Mesoscale Structures

Folds

Mesoscopic scale structures exist throughout the field area as small-displacement thrust faults and folds. The majority of these have fold hinge and axial surface orientations that mimic the larger structures (Fig. 4-14, Appendix I), suggesting they formed in the same strain field. These folds occur in nearly every unit, with folds in thick, strong carbonate and sandstone beds being more concentric and open, forming by flexural slip. Folds in mixed lithologies exhibit more strain in weaker shaley and silty lithologies (thickened hinges and thinned limbs [mostly shale]) controlled by the strong sandstones and carbonates, which tend to exhibit more parallel fold style (Fig. 4-15). Kink-style folds tend to form in shale-dominated layers (Donath and Parker, 1964).

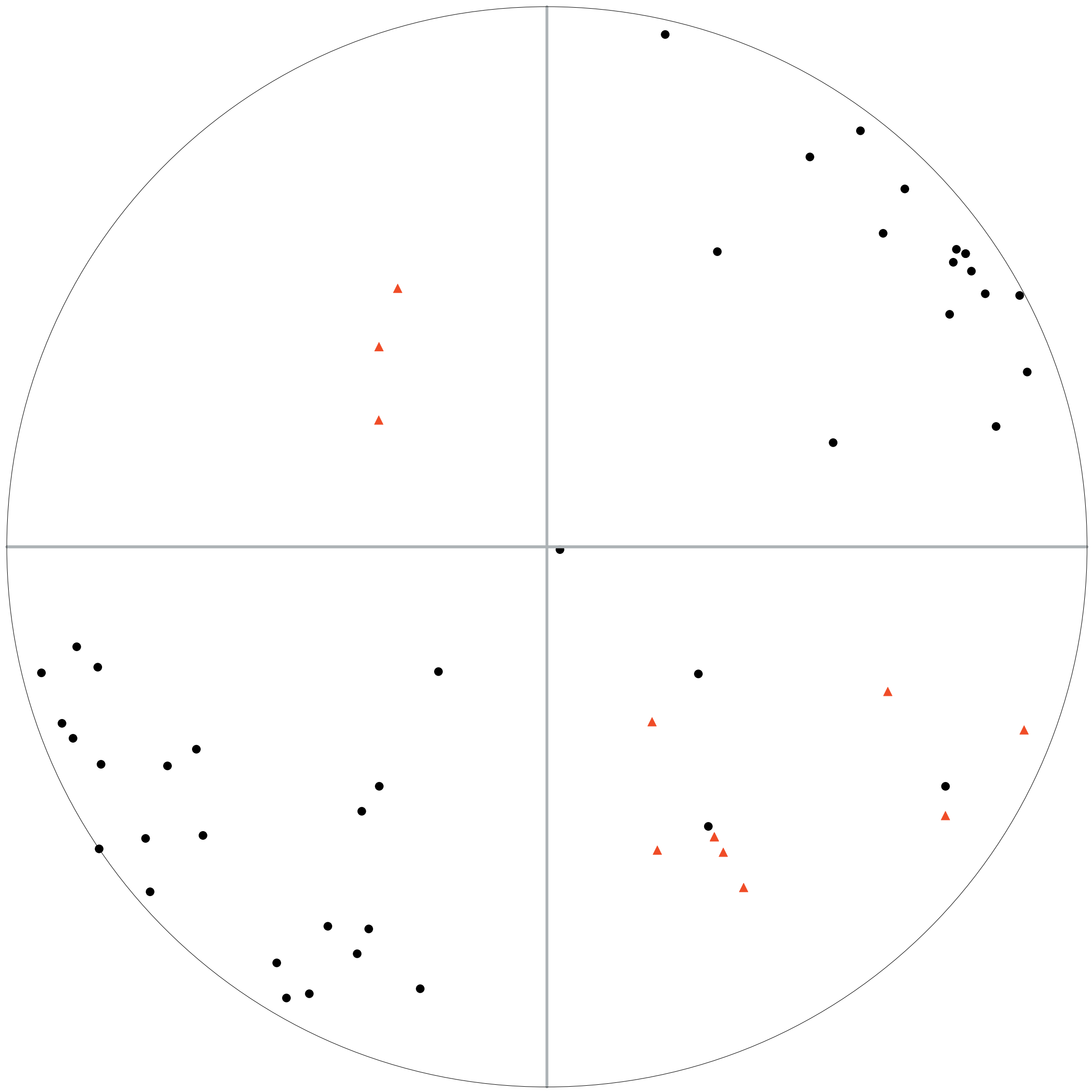

Figure 4-14. Lower hemisphere, equal-area stereographic projection of fold axes (black circles, n = 44) and poles to axial surfaces (red triangles, n=12) for small-scale folds in the Tellico-Sevier syncline. General trend of fold axes mimics the larger syncline. Plot made using StereoWin v. 1.2.0 by R. W. Allmendinger, 2002, Cornell University.

Figure 4-15. Fault-propagation fold in Bays sandstone along Sink road approximately 0.5 km (0.3 mi) north of Laurel Creek. Vergence is to the southeast. Picture is about 3 m (10 feet) tall.

Faults

Faults with displacement of a few meters or less are found throughout the field area and are most often found associated with folds. Most observed mesoscopic faults are in the hinges of fault propagation-style folds (Figs. 4-15 and 4-16).

Cleavage

Dominantly bed-perpendicular cleavage occurs in many locations in the field area (Fig. 4-17) and in many units including the Conasauga, Lenoir, Athens, Ottosee, Sevier, Bays and Chattanooga. All of these units contain some shaley or silty units, but, because of facies changes in each of them, cleavage is not pervasive or continuous in a single outcrop belt, even in the eastern Valley and Ridge. Cleavage planes have different appearance depending on the unit in which they are found. Cleavage in the Athens Shale frequently is a pencil cleavage where bedding and cleavage (both weak) present about equal anisotropies and are closely spaced, producing elongate shards where the rock is partially weathered (Fig. 4-18). Cleavage in the Ottosee and Sevier occurs in thicker discrete shaley layers interbedded with non-cleaved sandstone and limestone, and is often axial planar in folds. In some locations, the axial planar cleavage fanned slightly around the fold hinge, which may be caused by some additional tightening of the folds after initial folding and cleavage formation. The Bays, while containing much less shale than any of the other units, displays some of the best cleavage. Cleavage is prevalent in Lower Bays mudstone and refracts between sandier and siltier beds because of the mechanical contrast in properties of different lithologies (Fig. 4-19). Cleavage in the Bays is nearly bedding perpendicular and probably related to layer parallel shortening. The single good Chattanooga Shale outcrop (along Citico Road) contains very good cleavage throughout the exposed unit. Weathering expression differs between the Chattanooga and Athens with the intersection of bedding and closely spaced joints and subsequent physical weathering producing chips of Chattanooga Shale about the size of a

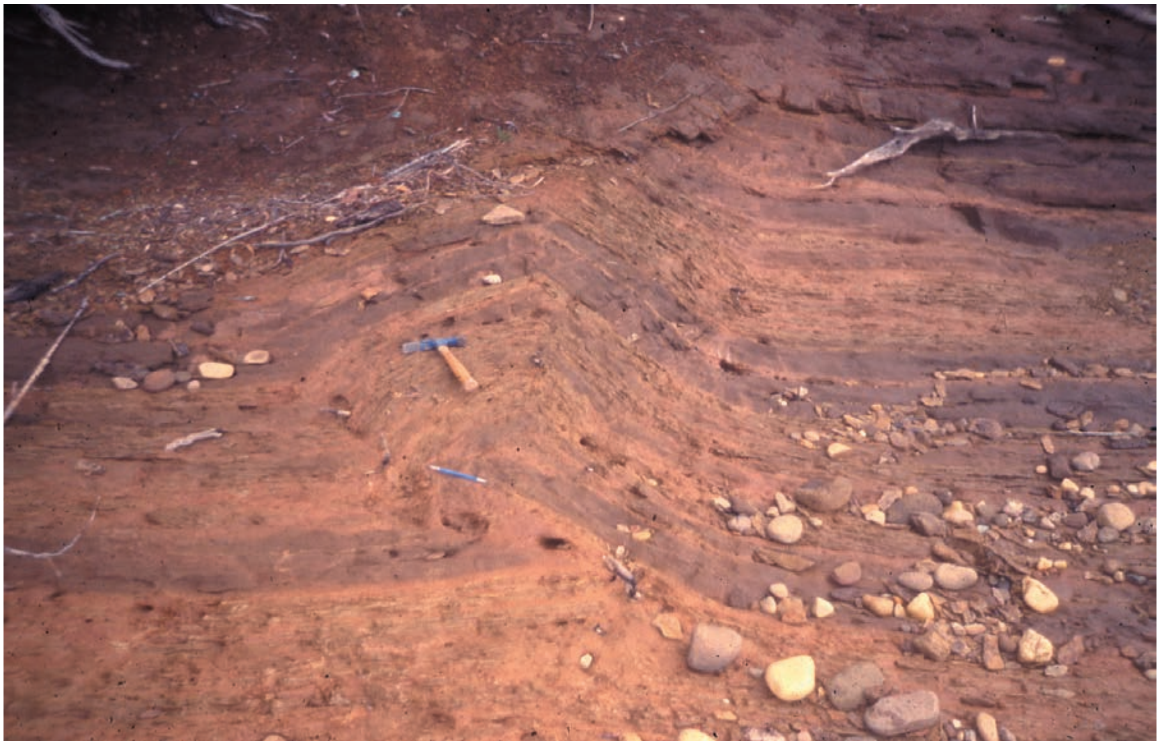

Figure 4-16 . Fault propagation fold in Sevier Shale along Tellico Reservoir along east shore of Bacon Bend. Darker beds are sandstone, lighter beds are shale. Note lack of displacement in sandstone bed above hammer. Hammer is 27 cm (11 inches long.. Red color is true weathered color (note gray-blue hammer head and blue pencil).

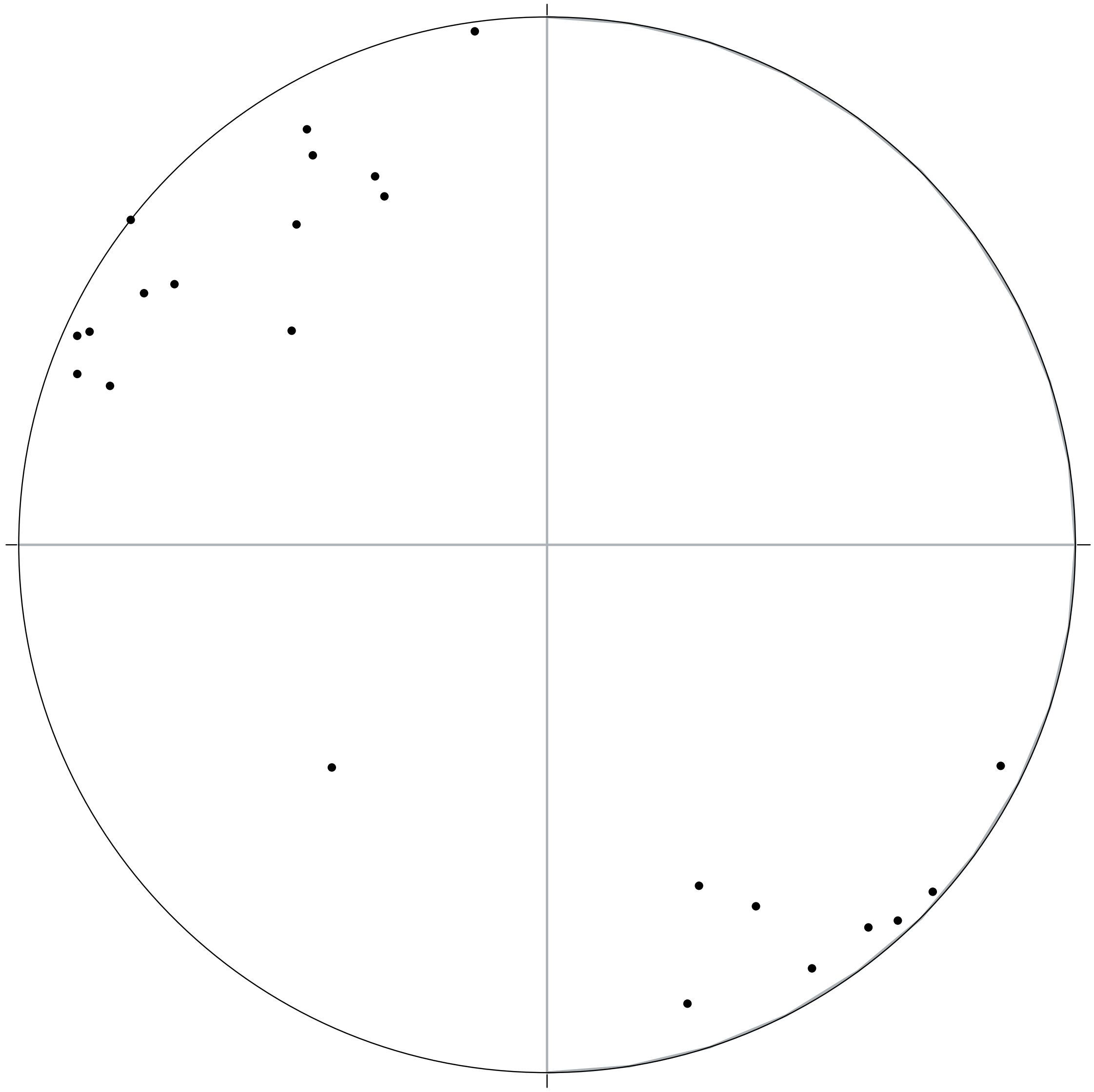

Figure 4-17. Lower hemisphere, equal-area projection of 23 poles to cleavage. Most cleavage is parallel to the axial plane of the larger structure (Tellico-Sevier syncline) or to secondary map-scale folds. Cleavage is perpendicular to bedding in most locations.

Figure 4-18. Pencil cleavage in weathered Athens Shale in the nose of the Kyker Bottoms anticline. Mechanical pencil is 15 cm (6 in) long.

Figure 4-19. Near vertical cleavage in the Bays Formation. Note prominence of cleavage in siltier layer (behind hammer) versus the sandier layers (above hammer). Hammer is 11 in long.

quarter versus the elongate pencils of the Athens due to intersecting of bedding and weak cleavage (Fig. 4-18).

Stylolites

Tectonic stylolites occur in limey beds of the Chapman Ridge, Sevier, and Ottosee formations, but are not extensive. Heath (2003) observed numerous stylolites in the hinge of the Tellico-Sevier syncline, but few are present to the northeast in the body of the syncline.

Cross Sections

Three cross sections were constructed across the syncline perpendicular to the axial trace at the same scale as the detailed geologic map (Figs. 4-20 and 4-21, Plate IV). The locations of the lines were chosen to cross prominent secondary structures to reveal details as well as determine changes in geometry of the main structure at depth. Depths to basement were calculated using thicknesses from the detailed geologic map (Plate I) as well as industry seismic data not available to previous workers.

Previous Cross Section Interpretations

Previous cross sections drawn through this area (Kashfi, 1971; Roeder et al., 1978; Woodward and Gray, 1985; Martin, 1997; Thigpen, 2002; Heath, 2003) have contained many compromises affecting their accuracy including: not being extended to top of basement, incorrect unit thicknesses, and fault geometries shown to be unrealistic in seismic reflection data.

Cross sections drawn by Roeder et al. (1978) and Woodward and Gray (1985) through the Tellico-Sevier syncline are less detailed than those presented here (Fig. 4-22). Neither had good information to constrain depth to basement, and their basement elevations appear to be 2000 to 3000 ft too low in cross sections W-W’, X-X’, and Y-Y’ (Fig. 4-22) and 1000 to 2000 ft too low in cross section Z-Z’ (Fig. 4-22). Roeder et al.

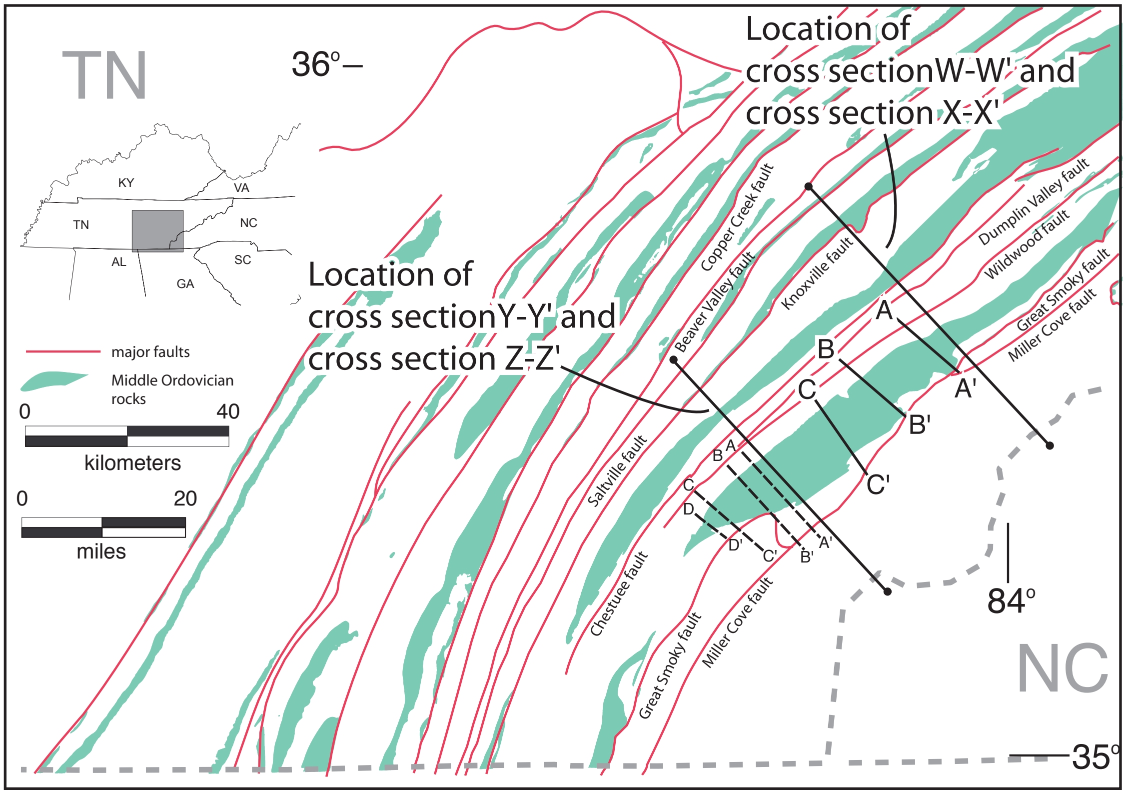

Figure 4-20. Location of Roeder et al., (1978) and Woodward and Gray (1985) cross sections through the Tellico-Sevier syncline. Cross sections W-W' and Y-Y' correspond to cross sections 7 and 8 in Roeder et al. (1978). Cross sections X-X' and Z-Z' correspond to cross sections 24 and 25 in Woodward and Gray (1985). Dashed lines, A-A' through D-D' are section locations from Heath (2003). Cross sections (Solid lines) A-A', B-B', and C-C' are the author's section locations.

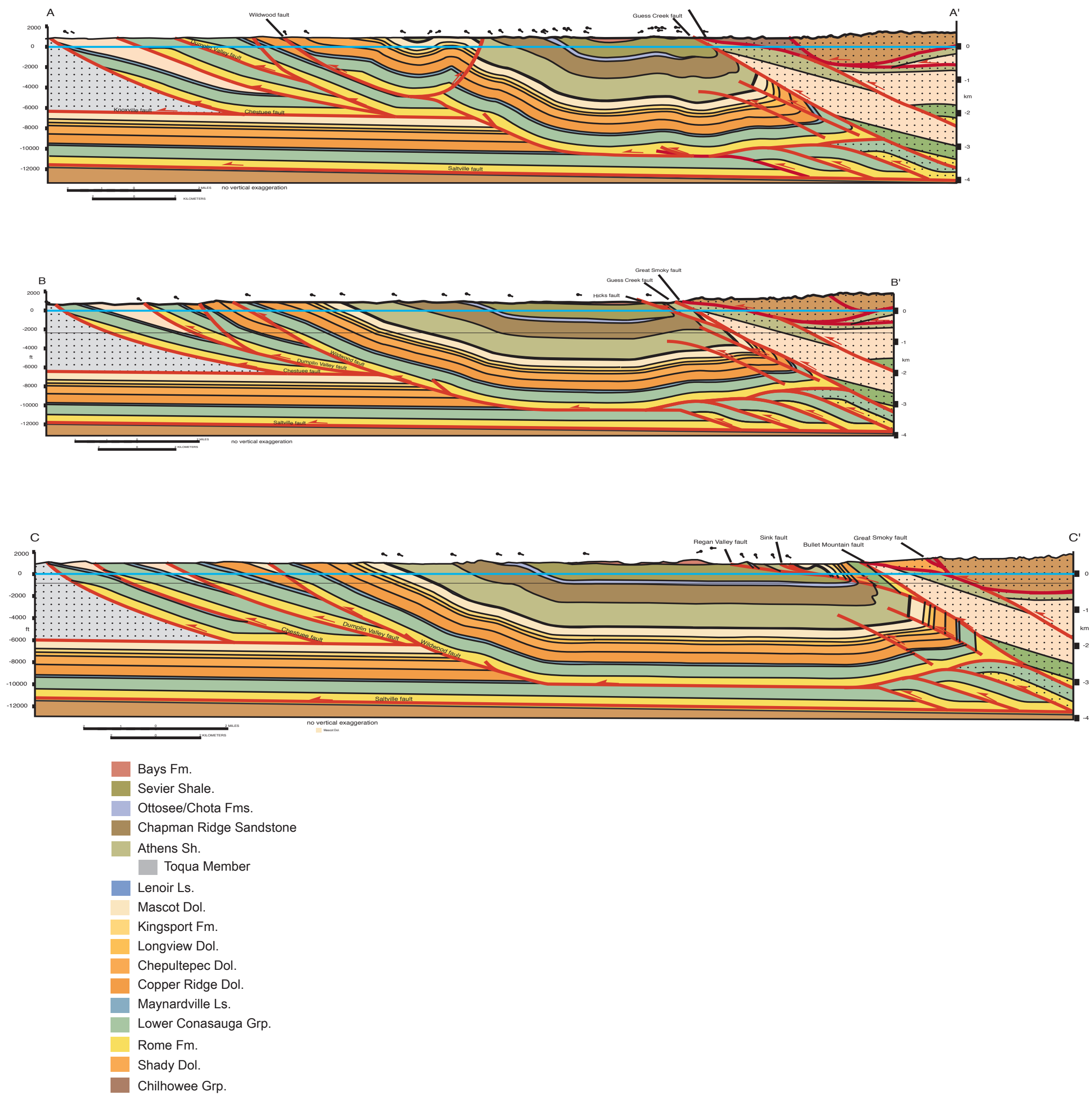

Figure 4-21. Cross sections through the field area. See Figure 4-20 for location of sections.

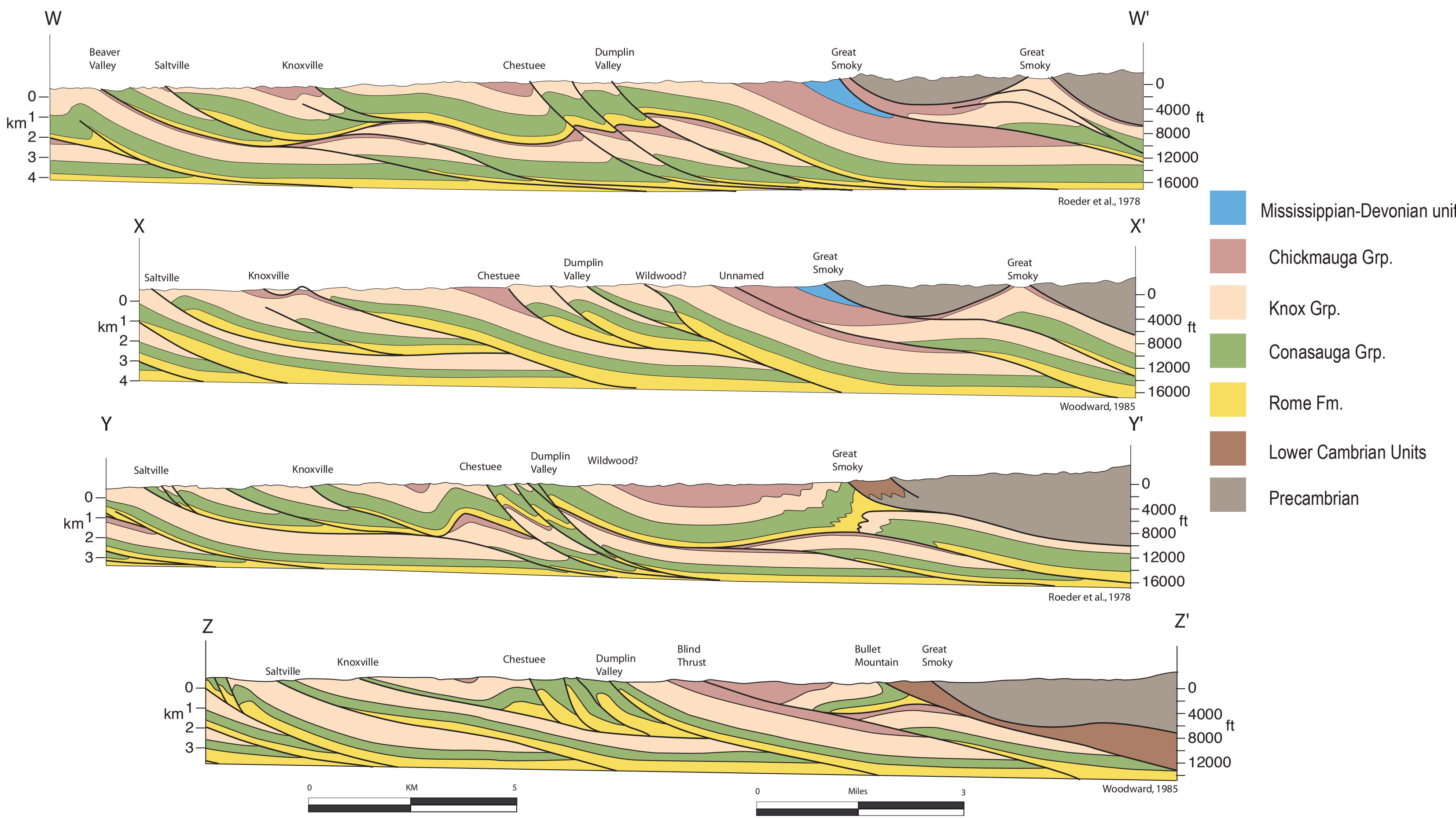

Figure 4-22. Cross sections W-W' and Y-Y' correspond to cross sections 7 and 8 in Roeder et al. (1978) . Cross sections X-X' and Z-Z' correspond to cross sections 24 and 25 in Woodward and Gray (1985).

(1978) (cross sections W-W' and Y-Y', Fig. 4-22) interpreted the Chestuee/Dumplin Valley/Wildwood sheet as initially being part of a continuous thrust sheet comprising the present-day Saltville, Knoxville, and Chestuee/Dumplin Valley/Wildwood sheets. This single sheet was later folded and faulted along with the underlying Copper Creek (cross section W-W', Fig. 4-22) or Beaver Valley (cross section Y-Y', Fig. 4-22) thrust sheet to produce the Chestuee, Dumplin Valley, and Wildwood faults. In the northern part of the study area, Woodward and Gray (1985) (cross section X-X', Fig. 4-22) depicted the Chestuee/Dumplin Valley/Wildwood fault system as a series of splays breaking essentially a single thrust sheet separate from the Knoxville sheet. South of the study area, the Chestuee, Dumplin Valley, and Wildwood are interpreted as minor splays in the Knoxville sheet (cross section Z-Z', Fig. 4-22). Roeder et al. (1978) and Woodward and Gray (1985) agreed that the Tellico-Sevier syncline at the north end of the study area appears as a monocline (since the southern limb is not present), although Woodward and Gray (1985) placed much of the Middle Ordovician and Devonian-Mississippian units in a second thrust sheet not originally associated with the Chestuee/Dumplin Valley/Wildwood system (cross section X-X', Fig. 4-22). South of the study area, their depictions of the syncline diverge. Roeder et al. (1978) (cross section Y-Y', Fig. 4-22) envisioned a true syncline, with a very highly folded and internally deformed southeastern limb folded upward by duplexing in the footwall of the Saltville/Knoxville fault. The complexly folded fault beneath the Blue Ridge thrust sheet, however, is probably kinematically impossible, and at the least, unnecessary. Woodward and Gray (1985) (cross section Y-Y', Fig. 4-22), on the other hand, depicted the syncline as an east-dipping thrust sheet (the northwest limb), whose far east end has been scraped off and displaced to the present-day surface along a blind thrust above a horse of unknown affinity. The displacement implied is not realistic because it requires nearly all of the southeastern limb (all but the tiny section above the tip of the blind thrust) to be disconnected from the northwestern limb, which is continuous from basement to the present-day surface.

Kashfi (1971) and Martin (1997), as well as Thigpen (2002) and Heath (2003), drew cross sections through the syncline at 1:24,000 scale. Kashfi's (1971) cross section was very shallow and did not address any complications at depth. Martin (1997) was the only one to draw a section to top of basement, although his cross sections extended northwest only into the southeastern limb of the syncline, which he depicted as existing at shallow depths above a blind thrust that ramps up through the Chestuee/Dumplin Valley/Wildwood thrust sheet beneath the frontal Blue Ridge, and extends into the upper Knox Group as a flat below the southeastern limb. His interpretation (Fig. 4-23) requires basement to be 900-1200 m (3000 to 4000 ft) too deep (he uses a depth to basement of between 4600-5200 m [15,000 to17,000 ft]), an unusually thin Chickamauga section (600 m [2000 ft] where detailed mapping indicates it should be at least 1600 m [5300 ft)], a northwest-dipping southeast-verging thrust fault between the Chickamauga and Knox in the southeastern limb of the syncline (not shown in his cross section), and an out-of-sequence faulting of the Blue Ridge.

Thigpen (2002) and Heath (2003) drew cross sections through the Tellico-Sevier syncline based on the assumption that rocks between the Chestuee fault and basement are decoupled from deformation observed at the present erosion surface. Thigpen (2002) did not retrodeform his section. Heath (2003) developed an interpretation that depicted a thrust sheet moving under a northwest-dipping blind fault to delaminate and fold up the southeastern limb of the syncline (Fig. 4-23). This thrust sheet was later cut off by out-of-sequence development of another thrust ramp bringing Chickamauga through Knox Group rocks up to the northwest as an anticline over the southeastern limb of the syncline, forming a wedge between and underneath both sheets. Geometrically, this model works and allows restoration of the deformed section, but it seems unrealistic

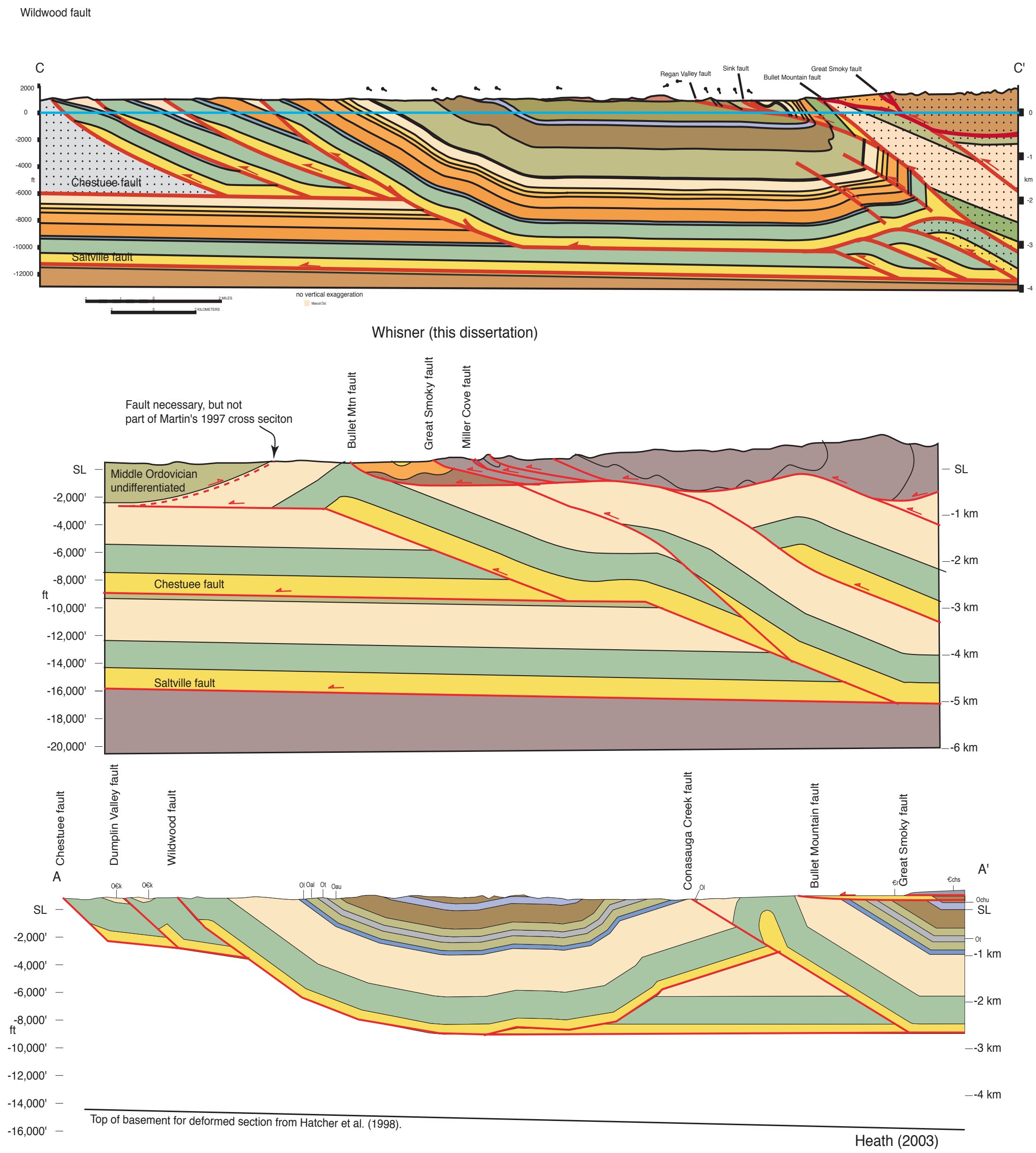

Figure 4-23. Martin's (1997), Heath's (2003) cross sections through portions of the Tellico-Sevier syncline, with cross section A-A'.

given that the same geometry can be produced more simply by in-sequence deformation of the footwall (which was not considered), and given the overall deformation style observed in the rest of the Valley and Ridge.

Cross-Section Discussion

One proprietary seismic reflection line crosses the western half of the syncline, along with detailed surface geologic data and stratigraphic thickness calculations, provides good constraints on the basement elevation (between 3600-4000 m [12,000 and 13,000 ft] below sea level [bsl]), the elevation of Chestuee/Dumplin Valley fault at the base of the syncline (2400-3000 m [9,000 to 10,000 ft] bsl), and the general geometry of the northwest limb of the syncline. Ramps generally occur in more competent layers, such as the Maynardville-Knox, and flats occur only in more shaly units (Rome and Conasauga shales). Although some variation in stratigraphic thickness likely occurs across the syncline, unit thicknesses are assumed to remain constant for cross-section construction purposes. Most deformation is assumed to have proceeded from hinterland to foreland, with only local out-of-sequence deformation.

The syncline evolved from the easternmost of a pile of imbricates that developed in sequence (Wildwood, Dumplin Valley, Chestuee) forelandward of the Blue Ridge-Piedmont thrust. Approximately 15 km (9 mi) east of what is now the base of the syncline, these imbricates were transported (along with the developing Knoxville thrust sheet) up a ramp from the Rome Formation basal decollement to a flat at the top of the Nolichucky Shale. After following the flat below the Maynardville-Knox for approximately 24 km (15 mi), the Knoxville/Chestuee/Dumplin Valley/Wildwood fault ramped upward again to a flat at the top of the Knox Group, finally coming to rest where the branch line of the Wildwood fault follows the top of the upper ramp (Fig. 4-21). The hinterland-dipping panel in the hanging wall of the Wildwood fault above the upper ramp is the northwestern limb of the syncline.

The area between basement and the Chestuee/Dumplin Valley/Wildwood fault is interpreted to be the Saltville thrust sheet. The entire package of Knoxville/Chestuee/ Dumplin Valley/Wildwood thrust sheets was displaced further forelandward on the Saltville sheet (Fig. 4-21). The Saltville fault, a low-angle, high displacement thrust at depth joins the master detachment below the northwestern limb of the syncline. Seismic reflection data suggest the Saltville thrust sheet exists below the Tellico-Sevier syncline and, although not imaged, the sheet could extend farther east. Heath's (2003) omission of rocks below the Chestuee/ Dumplin Valley thrust sheet allowed him to develop an unconventional wedge model to explain the faulting and folding associated with the Tellico-Sevier syncline. While his wedge model is retrodeformable and allows for clean cross-section balancing, it is not the most plausible solution. Heath's (2003) wedge can also be modeled as a horse or series of horses in the underlying thrust sheet lying above the basal detachment (Fig. 4-21). This duplex model tends to agree with a seismic reflection line that lies south of the syncline, cross sections in other portions of the Valley and Ridge (Boyer and Elliott, 1982; Mitra, 1986; Hatcher, 1991), and exposed duplexes in Tuckaleechee Cove and elsewhere. I propose that the southeastern limb of the syncline developed where continued shortening produced an out-of-sequence duplex in Rome and Conasauga shale in the Saltville sheet below the Wildwood fault. Three sub-thrust horses of the Saltville thrust sheet containing Rome and Conasauga shale fold up part of the Wildwood sheet, forming the southeastern limb of the syncline (Fig. 4-21, Plate IV). Smaller-scale folds and faults were subsequently superposed on the larger Tellico-Sevier syncline. Some minor gentle folds mapped at the surface are likely related to intra-formational deformation, but have been extrapolated downward to splays in the Rome. Splays in the Rome create restoration problems, but are geologically reasonable.

Tightening of the Kyker Bottoms folds led to fault thinning of the overlying Athens Shale (Fig. 4-5, cross section A-A'). The backthrust shown below the Kyker

Bottoms folds has only recently been exposed geologically and does not have much displacement or areal extent. It is only marked on the surface by overturned bedding in the Athens Shale and does not appear to extend to the southwest as far as Tellico Reservoir based on dip-strike data there (Fig. 4-1, cross section line A-A', Plate I). The existence of this fault is likely related to the difficulty of tightly folding Knox Group rocks involved in the Kyker Bottoms folds. As the fold tightened, it reached a critical closure angle where folding ceased and faulting became the dominant deformation style. The backthrust does not exist at the surface in B-B' or C-C' and is not shown at depth because of a lack of significant displacement evident on the surface. Only a small fold is evident in the adjacent cross section (B-B').

Surface dips of the eastern limb of the syncline have been steepened to overturned by later deformation related to the overriding Guess Creek fault. In addition, the advancing Blue Ridge fault mayhave detached a portion of the southeastern limb of the syncline creating a horse. The Belltown folds and the Sink fault (cross section C-C') present a series of problems. Dips within the Knox and Lenoir carbonates of the Belltown folds, as well as stratigraphic position, indicate a completely overturned package of rock (Fig. 4-5, Plate I and Plate IV and Cross Section [C-C']). For instance, the oldest rocks (Knox and Lenoir) lie at the center of what appears, based on outcrop pattern (Fig. 4-13), to be an anticline. Dip data, however, outline a syncline, so the conclusion reached is a synformal anticline. I interpret this to be the attenuated limb of syncline containing Knox deformed by the overriding Guess Creek Fault thrust sheet. The most plausible explanation is the Knox carbonates are detached from the underlying Athens Shale by the Sink fault and have been completely inverted. Trying to rectify the discrepancy between dip and outcrop pattern in the field, I assumed continued tightening of the Belltown folds eventually led to faulting, with folds accommodating displacement to the south, and faulting accommodating additional northwest-vergent displacement.

Completely inverting folded carbonates, however, requires a larger displacement fault, which would consequently be longer (Elliott, 1976). Heath's (2003) cross section does address the problem of overturned to inverted beds of Knox and Lenoir, allowing them to come from an unconnected anticline, rather than severely deforming the southeastern limb of the syncline. The extent of the fault to the south is still debatable, because fault displacement is buried under the Great Smoky fault and related splays and it places older Knox on younger overturned Athens. The correct fault orientation was not immediately recognized because Knox and Athens in the Belltown folds are still in the expected stratigraphic order for the larger Tellico-Sevier syncline geometry. The Sink fault may extend further south than Kashfi or I originally suspected. In fact, the Sink fault and the Conasauga Creek fault may be the same fault, observed by Heath (2003) and myself on either side of the Tellico River Valley. Northwest of Tellico Plains, Martin (1997) depicted a blind fault beneath the Great Smoky thrust, which tips out in the Knox Group (Fig. 4-23). This fault may be the Conasauga Creek/Sink Fault, but is in the unmapped portion of the southern limb of the Tellico-Sevier syncline leading Martin (1997) to conclude that it terminated in the Knox.

The faulting and folding at Belltown can be interpreted in a variety of ways depending on assumptions made about the response of the thrust sheet to the overriding Guess Creek/Blue Ridge-Piedmont sheet, the timing of folding/faulting, displacement on the fault, the original location of the overturned Knox-Lenoir package, and the timing of all of this related to the arrival of the Blue Ridge rocks. I have chosen to bring the overturned to inverted Knox and Lenoir in on a shallow fault related to deformation caused by attenuation of the southeastern limb and movement on overlying Guess Creek Thrust sheet. This is footwall deformation and contributes to the overturning of the southeastern limb of the Tellico-Sevier syncline.

If the duplexes developed beneath the Blue Ridge-Piedmont thrust sheet, it should be bowed upward along with the eastern limb of the Tellico-Sevier syncline. There is no evidence, however, for this in the outcrop pattern of the Chilhowee Group in previous maps (Martin, 1997; Heath, 2003; Wiener, unpublished). This suggests late out-of sequence movement of the Blue Ridge-Piedmont sheet over the existing Tellico-Sevier syncline.

The extra thick Athens Shale between the Sink and Conasauga Creek faults may be a mushwad (Thomas, 2001) that formed in the footwall of the Great Smoky fault as the overlying Knox and Lenoir were completely overturned—a window into the footwall deformation under the Blue Ridge. This is a more detailed variation of the Roeder et al. (1978) sections that show deformation in the southeastern limb although it is depicted as folded more like ductile rocks of the Blue Ridge. An intriguing test of this hypothesis would be to obtain water well logs from the Knox to see if the sheet is truly very thin with perhaps the Athens Shale underneath.

Conclusions

- The Tellico–Sevier syncline appears to be a simple structure at small scale but as scale of mapping increases, complexities emerge.
- Thickening of shale is likely related to folding and thinning of shale is likely related to faulting.
- The Tellico-Sevier syncline began its existence as a broad upright syncline that formed above the upper ramp of the Chestuee/Dumplin Valley thrust sheet (movement on the Dumplin Valley thrust and to a lesser extent the Chestuee fault and subsequent erosion removed all remnants of the hanging-wall anticline). The northwest limb of the future syncline was then modified into a syncline by duplexing (Boyer and Elliott, 1982; Mitra, 1986) in the underlying Saltville sheet, steepening the southeastern limb. The syncline was further deformed by the overriding Guess Creek thrust sheet attenuating the southeastern limb and

causing the complicated deformation pattern seen today.

- The Belltown folds may be part of a small sub-Guess Creek thrust or series of thrusts, heretofore unidentified, based on the disconnect between orientation of bedding in the Knox and outcrop pattern.
- The Dumplin Valley fault has at least 15 km of movement and the Chestuee fault has similar displacement as the Dumplin Valley has transferred displacement to the Chestuee. Faulting within the syncline has accommodated another few kilometers of shortening. This movement, combined with displacement on the Chestuee and Dumplin Valley fault, may be up to 42 km.
- Heath's (2003) wedge model requires a large amount of displacement on the Conasauga Creek fault (more than is apparent merely by observation of the stratigraphic units on either side of the fault). My duplex model still permits greater than apparent surface displacement on the Conasauga Creek fault, especially if it is related to the Sink fault of Kashfi (1971).

CHAPTER 5

PALEOSEISMIC INVESTIGATION

This chapter was accepted for publication in *Southeastern Geology,* v. 42, no. 2, September 2003.

Whisner, S. C., Hatcher, R. D. Jr., and Munsey, J. W. Disturbed sediments in the East Tennessee Seismic Zone: Evidence of large prehistoric earthquakes in east Tennessee? *Southeastern Geology,* v. 42, p.67-82

My contributions to the paper are: 1) most of the writing 2) most of the data collection and interpretation at the study sites. A note should be made that both of these sites were identified by other workers; Jeff Munsey at Tellico Plains and Larry Bolt and Harry Moore at the Gray Fossil Site. Although remote sensing techniques were applied to the search for evidence of earthquakes described in this chapter, only aerial photography had the spatial resolution required to discern surface deformations at a scale common in other intraplate settings. Aerial photography did not record any clues about the deformation at the Tellico Plains site supporting the use of foot traverses as the primary investigation technique for earthquake evidence in this area. Aerial photography may work however in other areas with large modern flood plains.

Abstract

Earthquakes occur in the East Tennessee seismic zone with greater frequency than anywhere east of the Rocky Mountains outside of the New Madrid seismic zone and the Charlevoix region in Canada. No earthquakes greater than M = 4.9 have been recorded in the East Tennessee seismic zone, although the observation window of historical seismic activity is narrow. It is possible that large earthquakes have occurred in the past, but the absence of large historical earthquakes has discouraged study of this seismic zone. The concentration of critical infrastructure and large population centers without knowledge of the earthquake history of this area is potentially dangerous. Two localities where anomalously deformed sediments occur have recently been discovered in the East

Tennessee seismic zone. An outcrop of disturbed and folded sediments in Tellico Plains, Tennessee, and filled fractures and faults in a Miocene lake deposit near Gray, Tennessee, could be the result of seismic activity. These features, combined with the level and extent of instrumentally detected seismicity, emphasize the need for continued study to properly assess the seismic hazard of this zone.

Introduction

Seismic hazard assessment is ideally based on estimated recurrence intervals of earthquakes with moment magnitudes $M>5.0$ (Bollinger and others, 1993; Frankel and others, 2002). Large earthquakes ($M \geq 6.5$) are frequent along faults at the active plate boundary in the western United States. Shorter recurrence intervals of large earthquakes place better spatial and temporal limits on these assessments. Despite being considered a stable intracratonic region (Johnston and others, 1994*)*, large prehistoric damaging earthquakes, like the 1811-1812 New Madrid sequence, have occurred in the eastern United States (Russ, 1979; Zoback and others, 1980; Russ and others, 1981; Johnston and Nava, 1985; Talwani and Cox, 1985; Van Arsdale, 1986; Obermeier, 1989; Zoback, 1992; Schweig and Van Arsdale, 1996; Tuttle and others, 1996). Because of the long recurrence intervals of large earthquakes, hazard assessment in this region is more difficult and based almost entirely on single large historical events or event clusters and statistical assessment, not on modern seismicity. The 1727 and 1755 Cape Ann, Massachusetts, the 1811-1812 New Madrid, and the 1886 Charleston earthquakes are the best-documented large historical events in the eastern United States and these areas are considered high hazard primarily due to relatively short repeat times for large events (Ebel, 1984; Frankel and others, 2002). Conversely, seismic hazard determinations for regions without documented, large historic or pre-historic earthquakes (e.g., East Tennessee Seismic Zone) are typically much lower even when small earthquakes are common within these regions.

While the maximum magnitudes of large earthquakes in the eastern and western U.S. are similar, the areal extent of damage is likely to be very different. Lesser attenuation by the more intact eastern United States crust has meant that large earthquake damage extends over a region approximately twice as large as that affected by comparable earthquakes in the western United States (Bollinger and others, 1993). For instance, the Cape Ann earthquakes (estimated M = 6.1) damaged Boston and eastern Massachusetts and were felt by ships at sea 300 km away (Stover and Coffman, 1993). The Charleston earthquake (estimated M = 7.3) (Johnston and Schweig, 1996; Talwani and Schaeffer, 2001) affected most of the United States east of the Mississippi. Four of the New Madrid events that occurred in 1811-1812 produced an estimated magnitude of at least M = 8.1 (Johnston and Schweig, 1996); they were felt over most of the eastern United States. Physical evidence of Charleston and New Madrid events includes soft-sediment deformation, sand geysers and dikes, small fault scarps, and damaged man-made structures. These areas have therefore been studied intensely to determine the future risk of large earthquakes. The New Madrid region is unlike Charleston and Cape Ann because it continues to produce many small magnitude earthquakes (Bollinger and others, 1991). Although it lacks a large documented earthquake, the East Tennessee seismic zone (ETSZ) is otherwise very similar to the New Madrid seismic zone in terms of modern seismic activity. This study was conducted to determine if there is evidence of large Holocene earthquakes to better assess the seismic hazard of eastern Tennessee in light of the region's concentration of seismicity.

East Tennessee Seismic Zone

Earthquakes occur frequently within the East Tennessee seismic zone (ETSZ) (Moneymaker, 1954, 1955, 1957, 1958; Bollinger, 1973; Bollinger and others, 1976; Chapman and others, 1997) (Fig. 5-1). It produces more earthquakes per year than any seismic zone east of the Rockies except for the New Madrid seismic zone and Charlevoix

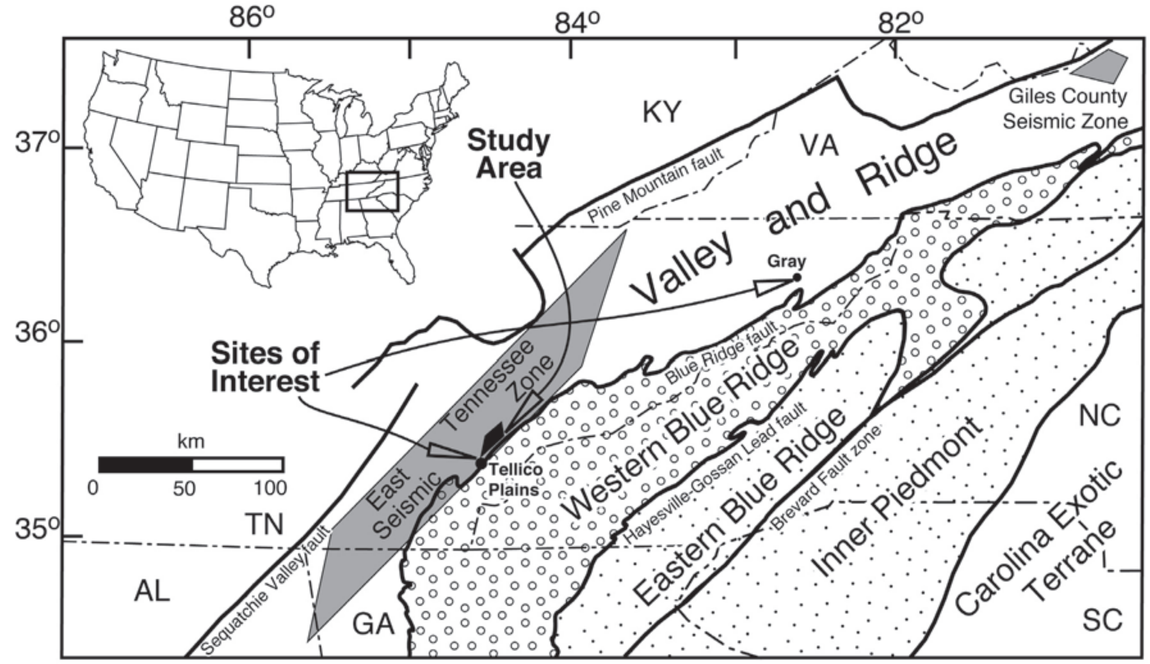

Figure 5-1. Simplified tectonic map of the southern Appalachians showing the location of the Valley and Ridge, the sites studied, and the Giles County and East Tennessee seismic zones. Modified from Hatcher and others (1990).

region in eastern Canada. Most earthquakes in the ETSZ are generated at depths of 8 to 25 km (Chapman and others, 1997) and are thus located in crystalline basement below the thin-skinned Valley and Ridge foreland fold-thrust belt (Fig. 5-2). The 1897 earthquake in the Giles County seismic zone (GCSZ) in Southwest Virginia (estimated M = 5.8), the largest earthquake recorded in the southern Appalachian Valley and Ridge, may have caused surface faulting and folding (Callis, 1996; Law and others, 2000). Although earthquake density is higher in the GCSZ, the GCSZ has a lower overall rate of earthquake occurrence, and is separated from the ETSZ by a region of low earthquake activity. The two largest earthquakes in the ETSZ, the April, 2003 M_{BLg} 4.9 earthquake in Mentone, Alabama, (now the largest earthquake recorded in this zone) and the 1973 M_S 4.6 earthquake that occurred near Maryville, Tennessee, damaged nearby chimneys, walls, and windows (Stover and Coffman, 1993). Earthquakes of this size are not large enough to cause more than very localized surface deformation and damage, and the largest recorded earthquakes in the ETSZ are below the accepted M~5 threshold for surface rupture/displacement (McCalpin, 1996).

First-motion studies of many instrumentally recorded earthquakes in the ETSZ indicate primarily north-south or east-west strike-slip motion (Fig. 5-3; Chapman and others, 1997). Seismologists have modeled the focal mechanisms (Teague and others, 1986; Chapman and others, 1997), created seismotectonic models (Powell and others, 1994; Kaufman and Long, 1996) to better understand the seismicity, and measured the stress field in the area (Zoback, 1992). Powell and others (1994) examined records from 1698-1977 and concluded the earthquake zone may have moved during the almost three centuries from the North Carolina-Tennessee border region to wholly within Tennessee. Given the decreased accuracy of historically recorded earthquakes versus the instrumentally located earthquakes, this apparent movement of the locus of earthquakes may reflect human population movement as much as movement of seismicity over such a

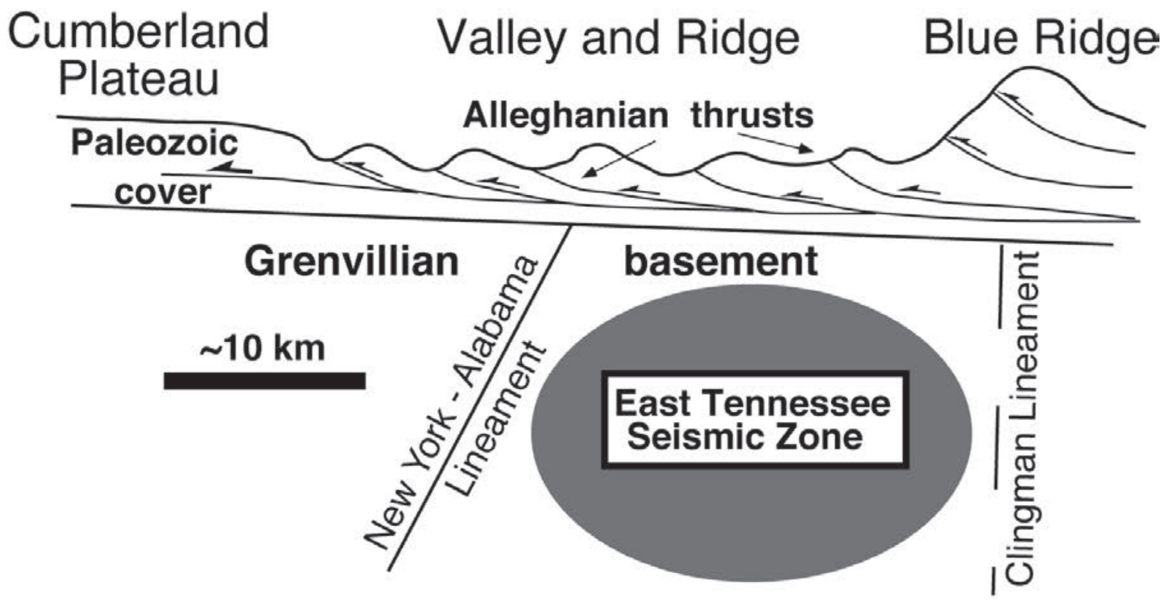

Figure 5-2. Schematic cross section of the crust in and near the ETSZ showing average depth of earthquakes, locations of geophysical lineaments, and thickness of Paleozoic cover.

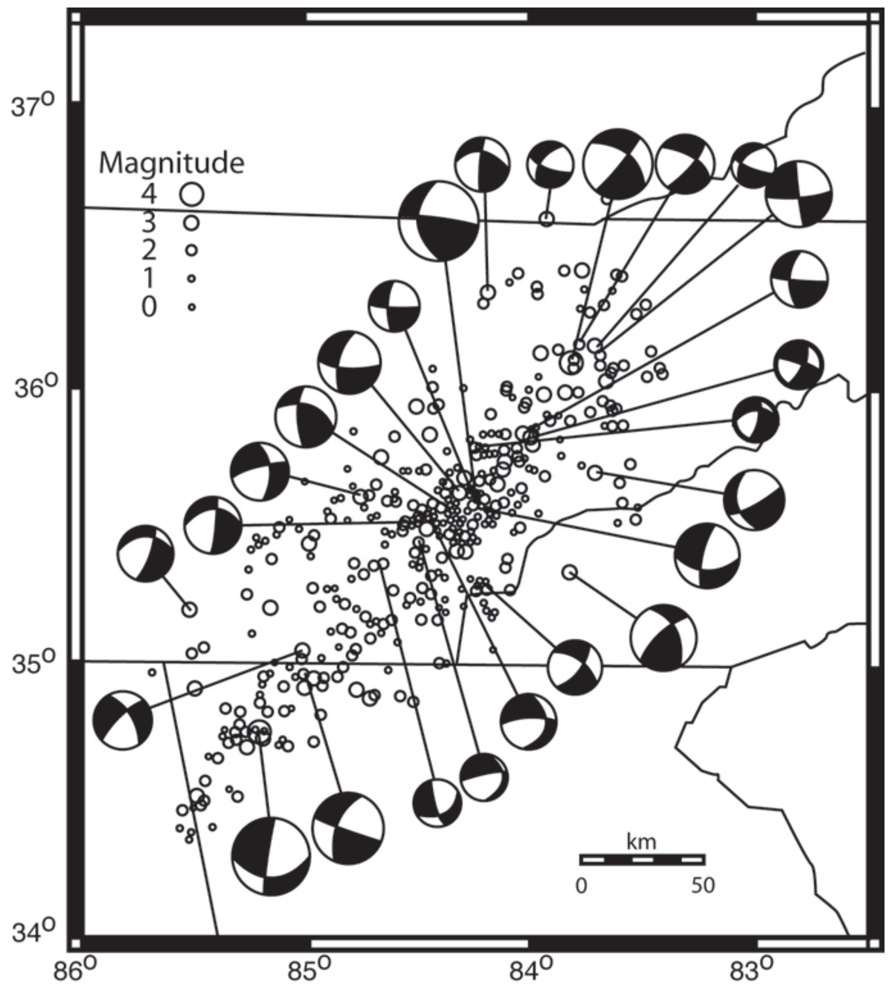

Figure 5-3. Lower hemisphere equal-area projections of first motions of earthquakes in the ETSZ. Most of the faults have strike-slip motion with very little vertical component. (From Chapman and others, 1997.)

short geologic time span.

According to the seismotectonic models, the earthquakes are concentrated between the prominent New York-Alabama magnetic and gravity lineament (King and Zietz, 1978) to the west and the weaker Clingman magnetic lineament (Nelson and Zietz, 1983) to the east. These anomalies are thought to represent boundaries between two different types of Grenville crust (Nelson and Zietz, 1983; Hatcher and others, 1987). The ETSZ is in a low seismic velocity crustal zone (6-6.2 km/s) flanked on either side by higher velocity zones (>6.3 km/s) (Kaufman and Long, 1996; Vlahovic and others, 1998). Hatcher and others (1987) suggested the New York- Alabama lineament is a seismic barrier that limits elastic strain accumulation and controls maximum earthquake size. Kaufman and Long (1996) hypothesized that the low velocity zone is a highly fractured and fluid-filled region in the crust. Faulting in Grenville basement rocks has been identified (Woodward and Gray, 1985; Mitra, 1988; Costain and others; 1989, Hatcher and others, 1994) and recently collected industry seismic lines in northeastern Tennessee show basement faulting passively affecting overlying Paleozoic structures (Tavernier, 2002), although the faults probably have not been active since the Eocambrian, perhaps due to their 042 orientation.

Given the modern seismic activity of the ETSZ and its similarity to the New Madrid zone in geophysical signature, areal extent, and shape (Powell and others, 1994), the current study was designed to determine if there have been damaging earthquakes in this region. Earthquakes have been reported in this area as early as 1776 (Moneymaker, 1954; Reinbold and Johnston, 1987), but none are known to have been large enough to cause geologically recorded disturbance. Given that large earthquakes in the ETSZ may have recurrence intervals of centuries, the lack of large historical earthquakes is likely related to the comparatively short historical record (Fig. 5-4). Considering that historical records here cover only the past 225 years and the heavy vegetation in this region, a large

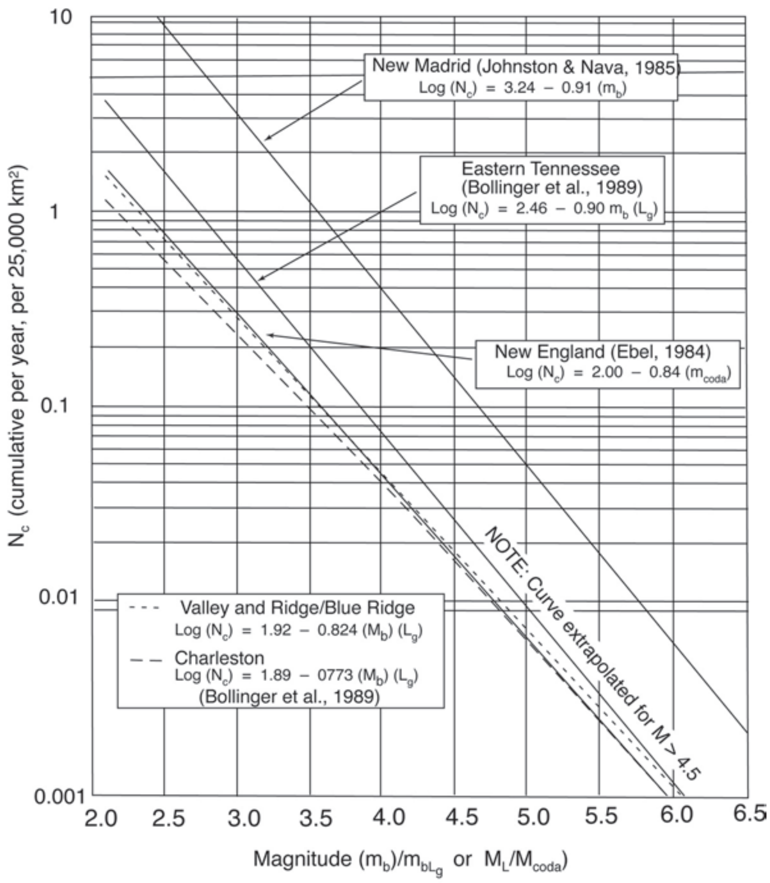

Figure 5-4. Curves showing magnitude of earthquakes against earthquakes per year per 25,000 km^2 plotted for seismic zones in the eastern United States.

prehistoric earthquake may have occurred here and not been detected. Earlier studies looking for evidence in this area have been reconnaissance (Cato and others, 1992) or anecdotal and related to other work (Delcourt, 1980).

Potential Earthquake Evidence

Evidence of past large earthquakes is divided here into two categories: primary and secondary. Fault scarps and other surface ruptures are examples of primary features that could be caused by earthquakes. Secondary features include drainage basin changes, landslides, and liquefaction features. All of these may occur in East Tennessee, but the humid climate with its rapid weathering and erosion, dense vegetation, topographically varied terrain, and human disturbance make them challenging to find (Ahnert, 1970; Crone and others, 1992; Machette and others, 1993). The most obvious geologic evidence of a recent earthquake is a fault scarp. This should produce a low ridge representing displacement between upthrown and down-dropped blocks of crust. Ideal strike-slip motion would produce little vertical offset, but pure strike slip motion is rare. Fault scarps would most likely be found through a combination of aerial photo analysis, drainage analysis, and field work. Distinguishing a small recent scarp in the 100 m or more of common relief in the East Tennessee Valley and Ridge is difficult unless the scarp can be observed in a flood plain or stream terrace, or cuts a prominent marker. Because most earthquake foci are located deep in the Grenville basement and because first motion studies indicate predominantly strike-slip faulting, formation and survival of fault scarps in Appalachian Valley and Ridge bedrock and younger cover may be unlikely. Drainage pattern analysis (Merritts and Hesterberg, 1994) may be helpful in finding surface deformation in a coastal plain, but is not applicable here because of strong bedrock control of drainage, particularly the northeast strike of Paleozoic units and prominent joint sets in the Valley and Ridge (Hatcher and others, 1992).

Earthquakes also trigger landslides (Jibson, 1996). Given the right conditions (dip of bedding, cleavage, or prominent fracture set parallel to the slope; weak material; water saturation; and steep slopes), even low magnitude earthquakes (M_b >4) can trigger landslides (Keefer, 1984). Occurrence of landslides, however, is not sufficient evidence of earthquakes. Landslides must be evaluated to determine if the mass movement could have been triggered by other means such as heavy rainfall or natural undercutting of slopes (Jibson and Keefer, 1993; Hatcher and others, 1996). This permits use of landslides as supporting evidence when independent proof of an earthquake trigger is found. Dating of material entrained in landslide deposits has provided links to earthquakes known independently from other geologic, paleoseismic, or historical evidence (Jacoby and others, 1992; Jibson, 1996).

Definitive evidence of large ETSZ earthquakes may ultimately come from liquefaction features. Liquefaction occurs where unconsolidated, water-saturated sediment is shaken during an earthquake, loses cohesion due to increased pore water pressure and dewatering, and undergoes spontaneous viscous flow. If an overlying impermeable layer is hydraulically fractured by this moving liquefied sediment, the sediment will propagate fractures until it no longer has the pressure to fracture the layer, forming sand dikes and sills (McCalpin, 1996). Removal of material beneath the impermeable layer may cause the layer to collapse, forming a crater, or move and fracture overlying sediments horizontally into discrete blocks by lateral spreading. If a sand dike reaches the surface, it may have enough pressure to form a sand geyser, also called a sand blow or sand boil. These features are all well documented where major earthquakes have occurred in unconsolidated sediment at Charleston, South Carolina (Obermeier and others, 1985; Talwani and Cox, 1985), New Madrid seismic zone (Russ, 1979; Obermeier, 1989; Tuttle and Schweig, 1995; Tuttle and others, 1996), Wabash Valley, Illinois (Obermeier and others, 1985; Obermeier, 1998), and along the Pacific Coast of Washington (Obermeier, 1994). Many of these features are readily observed in aerial photographs of major river flood plains, even where they are not visible at ground level. Liquefaction features are difficult to create aseismically, thus providing convincing evidence of earthquakes (McCalpin, 1996). Folded sediments and load structures may also be created by cyclic shaking by an earthquake, but can be formed by other geologic processes (Obermeier, 1996).

Location of Study

The location of the greatest concentration of modern earthquakes in the ETSZ is near Vonore, Tennessee (Fig. 5-5). One of the largest modern earthquakes in the ETSZ (M=4.2) occurred in Vonore in 1987. Detailed geologic mapping of bedrock and surficial materials was conducted in this area because of this high concentration. The Vonore, Tennessee, area is drained by the Little Tennessee and the Tellico Rivers. Both have well–developed flood plains; the Little Tennessee, the larger of the two, has a large flood plain that has unfortunately been largely inundated by a TVA reservoir. Extensive archeological work was performed on the flood plain of the Little Tennessee before it was dammed. The reports did not identify features such as sand dikes or offset beds that could be related to seismic activity (Chapman 1977, 1980), but one possible offset was observed in a prehistoric Native American stockade wall (Delcourt, 1980). The Tellico River is a tributary of the Little Tennessee, and a significant portion of its flood plain remains exposed. Both rivers have less exposed and less extensive older terraces. Although the Vonore area was considered the most likely place to find evidence of large earthquakes, other possibilities outside the immediate area were investigated. Landslides, precariously balanced rocks, soft-sediment deformation, fractures in soft sediment, liquefaction features, and other evidence that would suggest a prehistoric large (M>6) earthquake were all considered as viable targets for investigation.

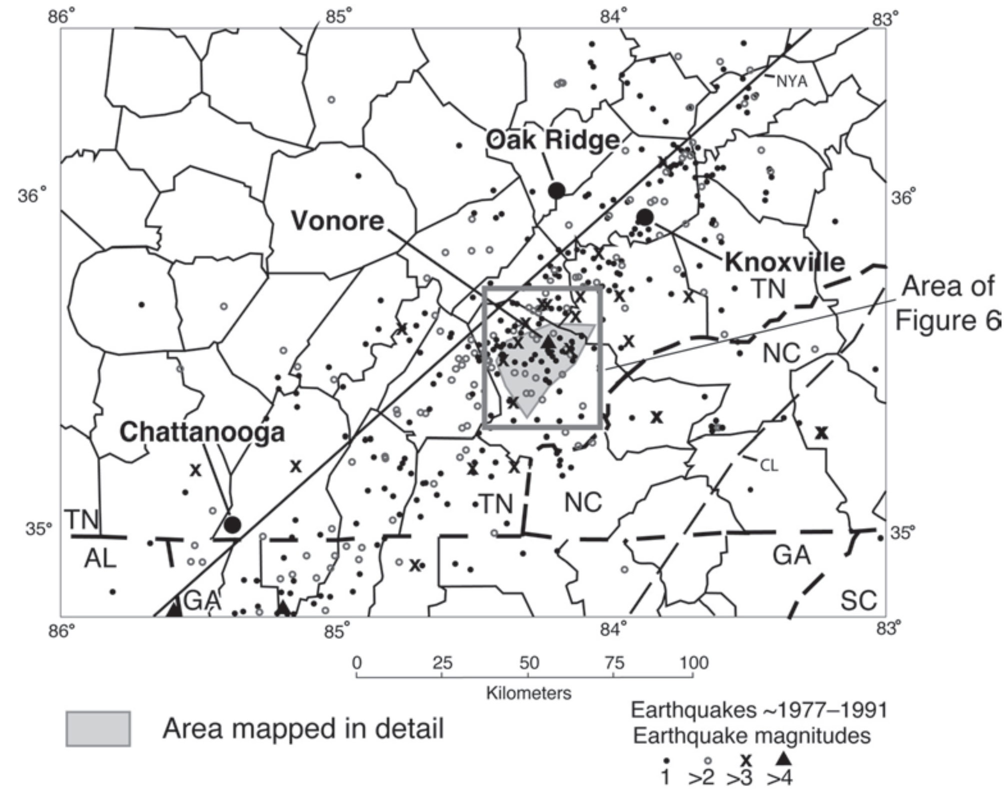

Figure 5-5. Earthquakes in the ETSZ 1977-1991 also indicating the location of the April, 2003 M=4.9 earthquake near Mentone, Alabama. Earthquakes are concentrated between the New York-Alabama lineament (solid) and weaker Clingman geophysical lineament (dashed). The greatest concentration of modern earthquakes occurs near Vonore, Tennessee.

Geologic Mapping

Detailed 1:24,000 scale geologic mapping of bedrock and surficial materials was carried out to better distinguish Alleghanian structures from those possibly related to large recent earthquakes. A geologic map was produced of the area between the Little Tennessee and Tellico Rivers (Fig. 5-6) by collecting data from foot, road, and canoe traverses along these rivers and between the Great Smoky fault (to the SE) and U.S. 411 (to the NW).

Traverses focused on locating throughgoing recent faults or liquefaction features in riverbanks that are not visible using other data sets such as aerial photography. Work along the Little Tennessee River also focused on the higher terrace deposits, which are more common there than along the Tellico River.

Flood plains and old river terraces are the most likely locations for finding geomorphological evidence of a major paleoseismic event. Studies of the New Madrid seismic zone focused preliminary searches along the banks of drainage ditches because of the increased likelihood of finding paleoseismic evidence in the ditch banks (Johnston and Nava, 1985; Van Arsdale, 1986; Tuttle and others, 1996). Terrace deposits have also been studied (Chapman, 1980; H.H. Mills, 1999, personal comm.), but the planar nature of these deposits and their proximity to water make them good farmland and consequently they are substantially altered. Tellico Reservoir, which now covers much of the flood plain and some of the lower terraces of the Little Tennessee River, is kept at an elevation of about 248 m (813 ft) during the summer months; during the winter, the reservoir is lowered 3 m (10 feet) exposing a small portion of the flood plain. Prereservoir soil surveys, aerial photographs, and topographic maps have been analyzed to determine probable locations for suspect sand blows and dikes near the current shoreline. No obvious sand blows or dikes were found using these techniques.

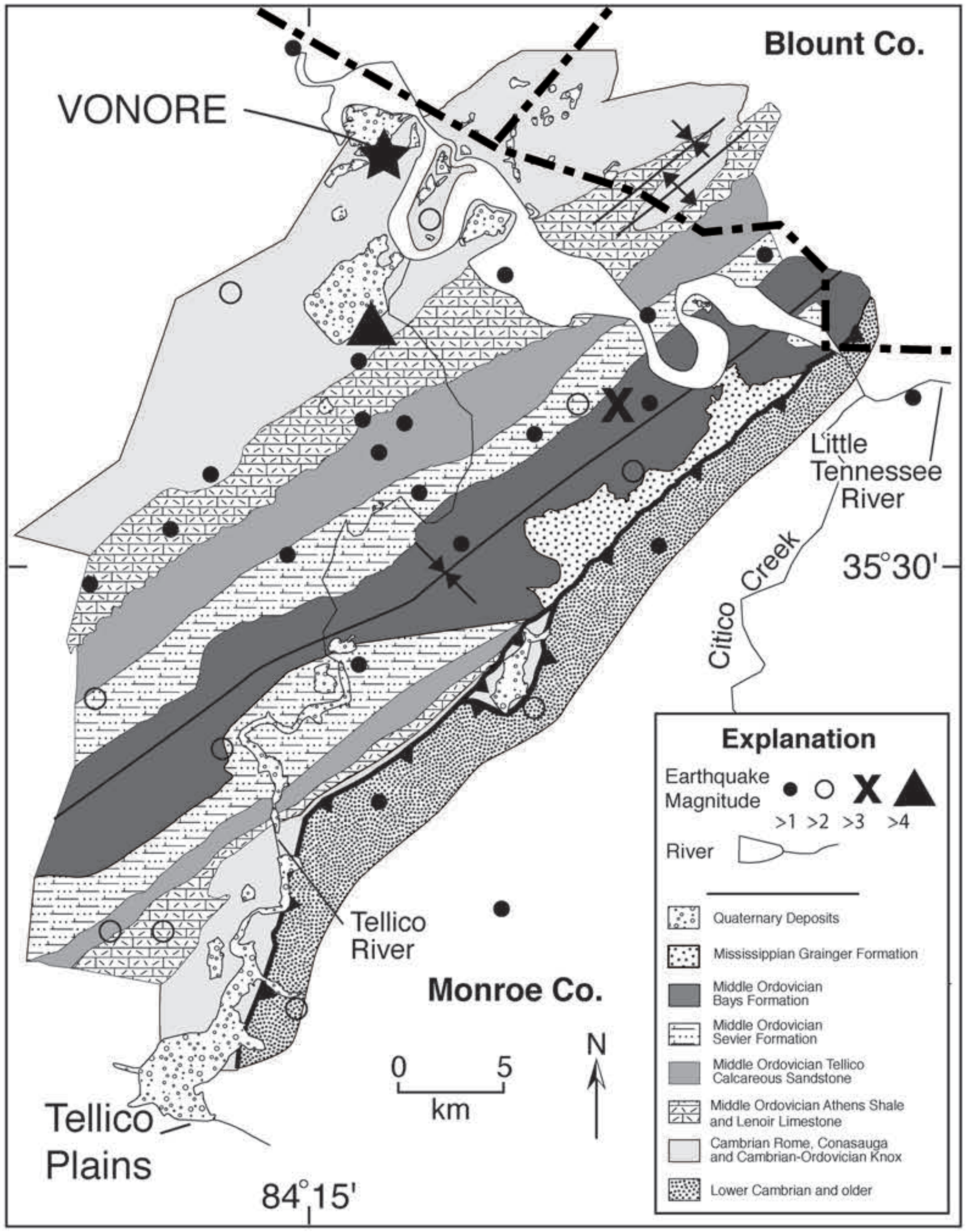

Figure 5-6. Detailed geologic map of the most active area in the ETSZ showing rivers and location of Tellico Plains (TP) disturbed terrace deposit. Teeth are on hanging walls of faults. The town of Vonore is marked with a star.

Other Study Areas

Two other sites have been studied and warrant more thorough investigation. The Gray fossil site in northeastern Tennessee has possible liquefaction features (clastic-filled dikes), and a site in Tellico Plains, Tennessee, had deformed deposits.

Gray Fossil Site

The Gray fossil site, discovered in the summer of 2000, is not within the modern boundaries of the ETSZ defined by Powell and others (1994). This site contains one of the few well-preserved Miocene mammalian fossil assemblages in the U.S. and only the second of Miocene age of any size (Whisner and others, 2001). This location, near Gray in NE Tennessee, (Fig. 5-1), is the site of a Miocene lacustrine deposit of organic fossil-rich clays and alluvium resting on Cambro-Ordovician Knox Group. The organic-rich black and gray Miocene clays are capped by orange cherty, sandy, clayey Quaternary alluvium (Fig. 5-7). Joints and fractures with little offset exist throughout the clay. These fractures predominantly trend east-west, northeast-southwest, or south-southeast (Fig. 5-8), orientations consistent with underlying bedrock orientations for Mesozoic and modern stress fields (maximum compressive stress 070) (Hatcher and others, 1992; Zoback, 1992). The existence of these fractures suggests possible inheritance from underlying bedrock, indicating movement since deposition, or they may be products of the late Tertiary to Holocene stress field (Engelder, 1982).

This site contains apparent dewatering features in the clay deposit (Fig. 5-9). The primary expression of dewatering is a clay- and gravel-filled fracture on the south side of the site. Occasional sand and gravel lenses exist throughout the deposit, one of which may have been cut, dewatered, and provided fill for the fracture during earthquake shaking or alternately sinkhole collapse (Figs. 5-9a and 5-9b). This fracture apparently propagated up-section from or through a layer of highly organic, less permeable clay into a cap layer of less organic, lighter-colored clay. It is not clear if it extended into

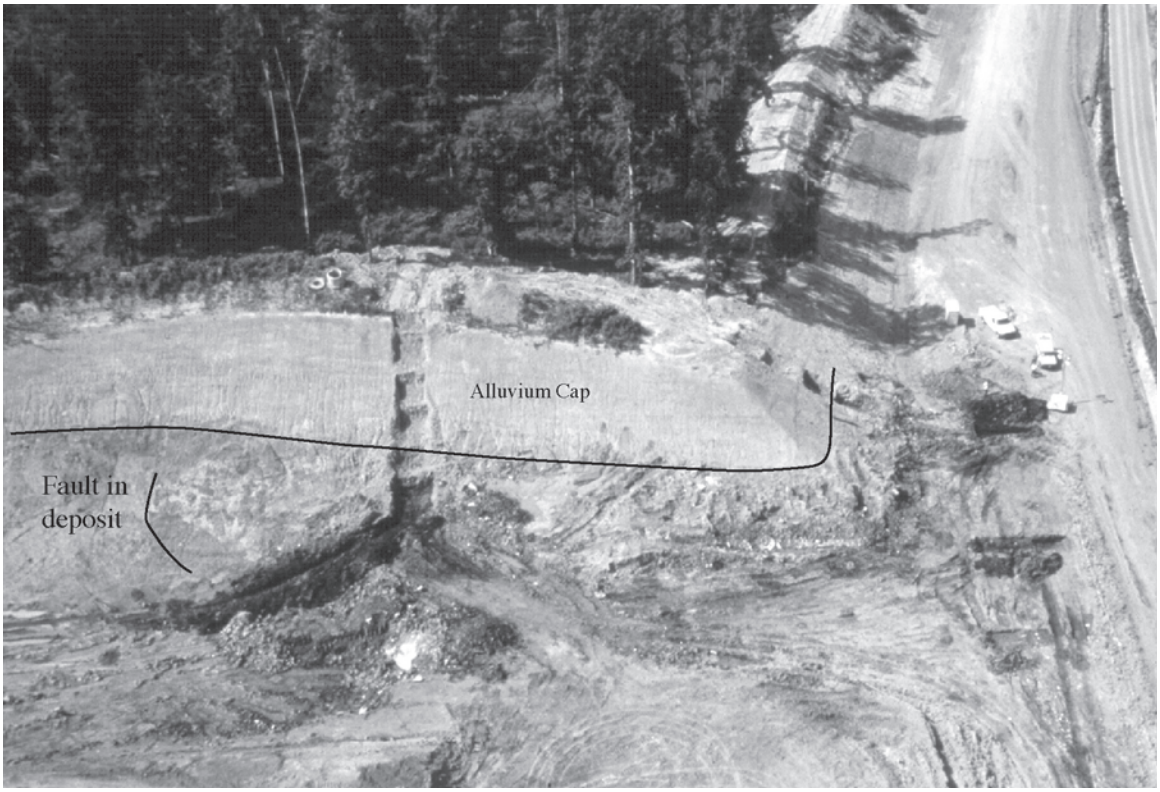

Figure 5-7. Aerial photograph of Gray site showing Quaternary alluvium cap over darker organic layer. Clastic-filled fault is highlighted to left of deposit. (Photograph courtesy of Harry Moore, Tennessee Department of Transportation.)

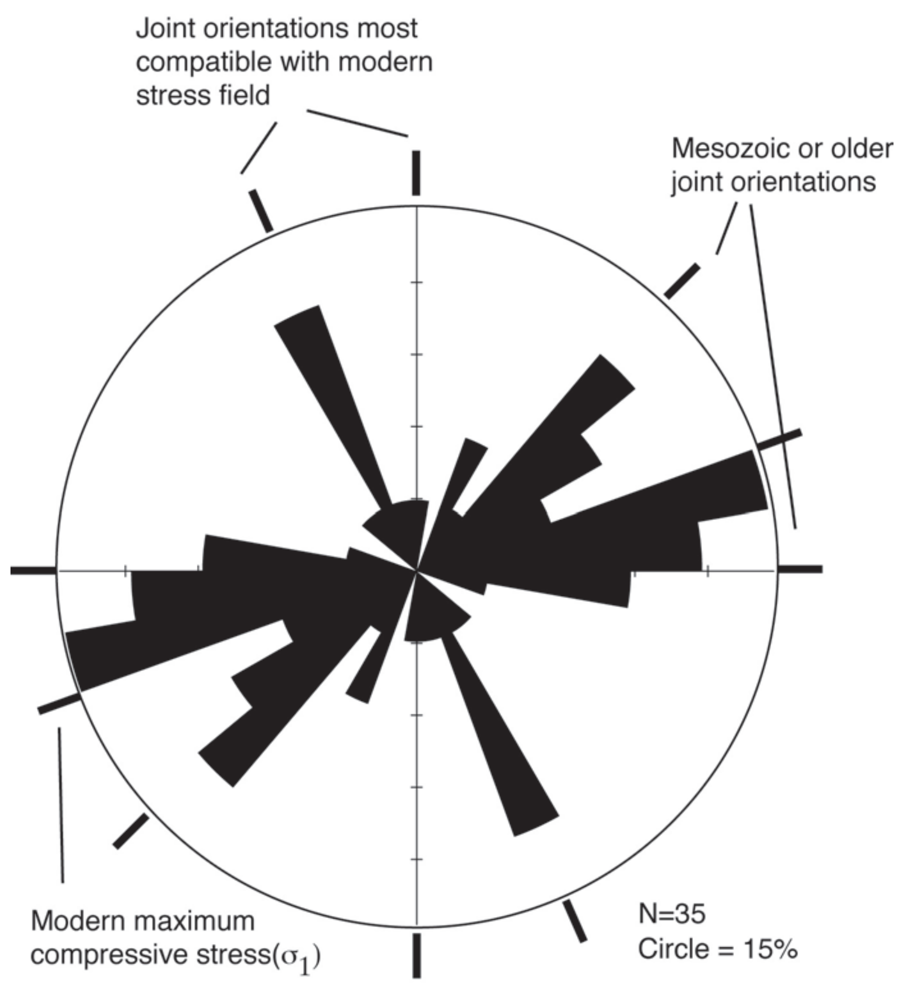

Figure 5-8. Rose diagram indicates fractures within the Cenozoic deposits at the Gray site are generally aligned with fractures in the underlying bedrock.

Figure 5-9a. Fault in Miocene Gray deposit clay looking south on a gently sloping surface. To the right is the upthrown block. Offset is a few meters. Line traces fault surface.

Figure 5-9b. Closeup of fault. Fill material is dark clay and pebbles. Knife is 7cm long.

the overlying alluvial layer. Although the fracture has an aperture of only a few cm, it is traceable up section for 5 to 10 m. This feature, while intriguing, was not studied in detail. More of these filled fractures exist, but the site has been covered with grass and is currently being preserved as a paleontological repository of Miocene fauna and flora, and trenching the fractures is presently not feasible.

Tellico Plains

In early October, 1999, a deformed deposit along the Tellico River was observed along a Tennessee Department of Transportation (TDOT) excavation widening Tennessee Highway 165 through Tellico Plains, Tennessee (Fig. 5-1). This deposit overlies Cambrian Sandsuck Formation siltstone in the hanging wall of the Great Smoky fault, and the extent of weathering (deep weathering rinds in cobbles) indicates at least an early Holocene or late Pleistocene age, although the absolute age is unknown.

After initial investigation, a trench was cut perpendicular to the face of the 3 m vertical exposure. Because this locality was scheduled for destruction during widening of the highway, trenching and investigation of the exposure were done during a short period of time before removal of the entire exposure by TDOT in November, 1999. Only one trench was excavated, and this trench yielded few data because the deposit pinched out over a very short distance perpendicular to the main cut and parallel to the trench (Fig. 5-10).

The deposit was composed of two layers: a lower disturbed zone containing cobbles ranging from saprolitized angular graywacke fragments to fresh rounded vein quartz in a silt and clay matrix, and an upper undisturbed zone of rounded fresh cobbles and pebbles composed primarily of vein quartz (Fig. 5-10). Most impressive in the disturbed zone was folded saprolite (Fig. 5-11). These layers were folded with the long axes of pebbles and cobbles aligned parallel to each other and to manganese oxide and hematite stains that marked bedding in folded layers and outlined fold geometry

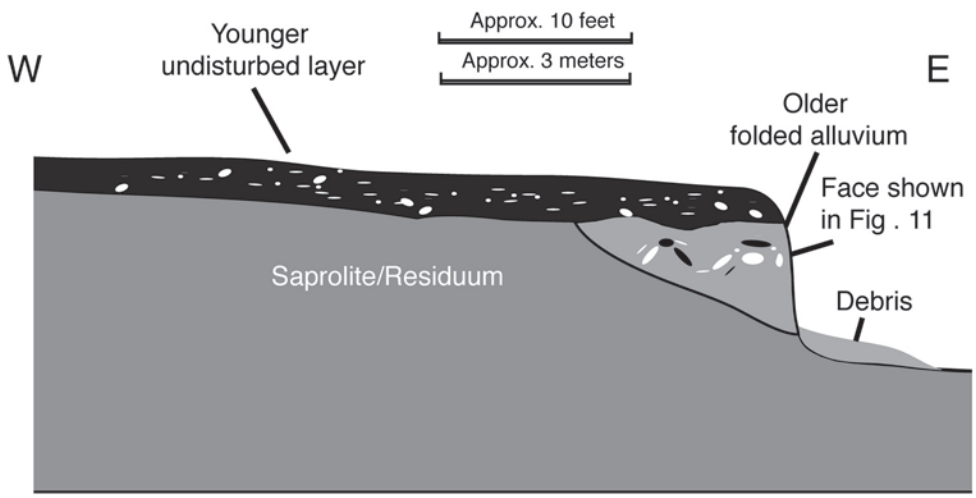

Figure 5-10. Cross section parallel to trench at Tellico Plains site located in Figure 5-6. Older folded alluvium consists only of a small wedge on the right portion of the section.

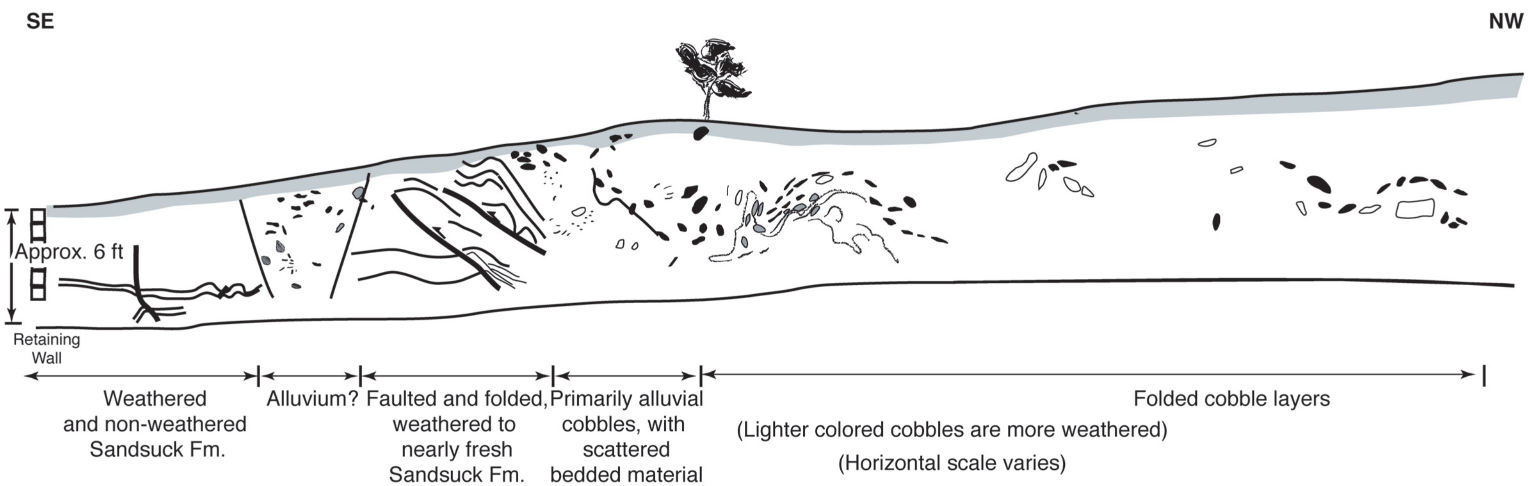

Figure 5-11. Schematic drawing of the disturbed deposit in Tellico Plains, Tennessee. Photos in Figures 5-12 and 5-13 were made in the right third of the sketch.

(Figs. 5-12 and 5-13). Based on measurements of cobble orientations within the five best defined folds of the cut face, fold axes were nearly horizontal and trended between 004 and 015 (Fig. 5-14), with axial planes mostly vertical. These orientations are nearly perpendicular to the face of the road cut and the river valley. Sandsuck Formation saprolite formed the cores of the folds. This saprolite could have been forced into the core of a cobble layer as a rising mass of liquefied material or folded with the cobble layers. Offsets of these layers define small planar fault zones with <10 cm displacement that were located southeast of the primary deformed zone (Fig. 5-14). The folds may have resulted from soft-sediment deformation and liquefaction triggered by a prehistoric earthquake. Alternatively, they could have been the product of dewatering and folding at the toe of a prehistoric landslide. With the possibility of human disturbance or other explanation for the deformation, however, more terrace deposits in the area need to be identified and investigated (Whisner and others, 2000).

Discussion

No features were observed near Vonore, Tennessee, that could be confidently attributed to a large earthquake. Many small faults and folds were observed during bedrock mapping, but these are all Alleghanian. Limited exposures of erosional remnants of higher terraces revealed no throughgoing faults or clastic-filled fractures. Aerial photograph analysis combined with careful review of the Monroe County soil survey (United States Department of Agriculture, 1981) revealed no unusual surface features that could be described as earthquake related. Traverses along the banks of the Tellico River found nothing but flat-lying cobble layers and massive sand, silt, and mud deposits in the modern flood plain.

Research at the Gray fossil site does not currently emphasize structural or neotectonic investigations. Additional study of the Gray site may ultimately reveal a connection between the sand dikes and earthquake activity. If so, the ETSZ may have had a much

Figure 5-12. Unscraped vertical face of Tellico Plains disturbed deposit. Box is location of Figure 5-13. Letters indicate cobble locations.

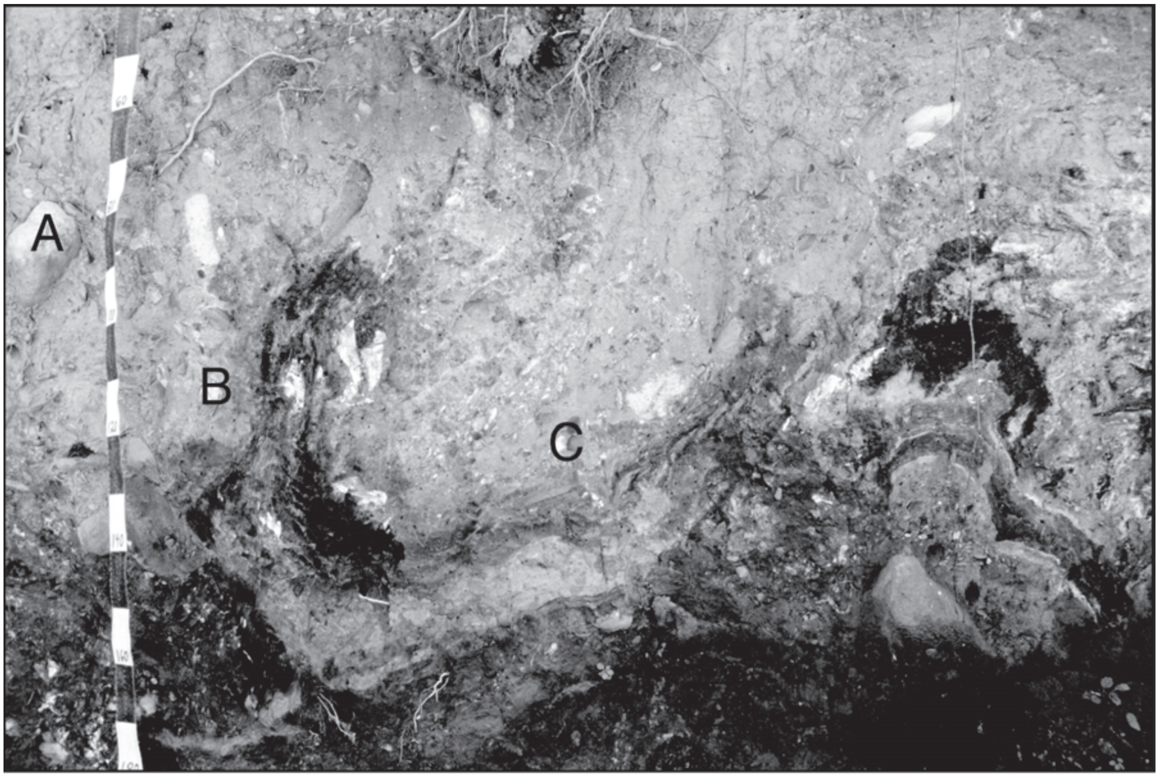

Figure 5-13. Scraped vertical face of Tellico Plains disturbed deposit. Letters indicate cobble locations in this photo and in Figure 5-12.

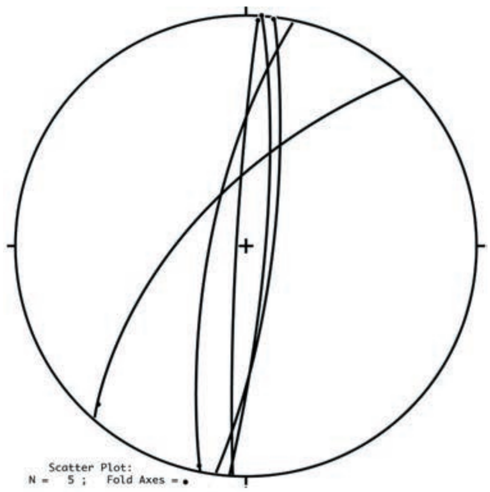

Figure 5-14. Lower hemisphere equal-area plots of orientations of folded cobble layers. The axes and axial planes of the five most prominent folds are shown.

greater extent and more lengthy history than is indicated by modern seismicity.

The Tellico Plains site, now removed by TDOT, exhibited potential liquefaction features. Only a small portion of the exposure was preserved, however, so the geometry, age, and extent of the folded beds remain unknown. The equivocal nature of the structures observed at this site and limited time it was available for study make finding another similar landslide or terrace deposit all the more important. Additional sites in the same area containing soft-sediment deformation would create a more compelling argument for an earthquake origin. Similar deposits of the same age, at similar elevations, have to date not been observed. The modern Tellico flood plain, but not smaller tributary streams, was traversed to identify disturbed sediments but none were found. Similar deposits along the Little Tennessee River contain only flat-lying, undisturbed fluvial deposits.

Conclusions

1. This is the first detailed geologic study in the ETSZ focused on trying to locate paleoseismic features. Some 300 km^2 of the most active part of the ETSZ (~1%) was mapped in detail without revealing concrete evidence of large prehistoric earthquakes. Many more square kilometers of unexplored stream valleys and terrace deposits that could entrain paleoseismic evidence exist in East Tennessee.
2. Clastic dikes in the small fault at the Gray fossil site could be evidence of prehistoric seismicity in an older, much more extensive ETSZ.
3. Folded and faulted pebble layers in an older landslide or terrace deposit beneath younger Tellico River alluvium at the Tellico Plains site could indicate early Holocene or late Pleistocene earthquake activity.

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APPENDICES

Appendix I

Cross Bed Measurements

Station	Latitude	Longitude	Bedding	Bob Bedding	Xbed	Xbed	Xbed	Xbed	Xbed	Xbed	Xbed	Xbed	samples
Arby's			N 74 E 17 S		S 45 E	S 48 E	S 43 E	S 35 E	S 3 E				
Xb-1	35.5965	84.0873	N 55 E 30 S		S 40 E	S 30 E	S 25 E						
Xb-2	35.5844	84.1215	N 30 E 36 S										
Xb-3	35.4146	84.3632	N 50 E 3 S		N 0 E	S 80 E							
Xb-4	35.4304	84.2849	N 40 E 80 S ot		S 35 E								
Xb-5	35.4421	84.2602	N 50 E 65 SE ot		S 35 E	S 22 E							
Xb-6	35.6049	84.0847	N 55 E 35 S		S 20 E	S 40 E							
Xb-7	35.5244	84.2466	N 60 E 27 S		S 30 E	S 80 E	S 35 W	S 70 W	S 26 E				
Xb-8	35.3463	84.4766	N 80 3E 20 N		S 10 W	S 50 W	S 5 W	S 60 W	N 5 W	N 35 W	S 10 W		
Xb-8a	35.3467	84.4743	N 60 E 9 N		S 20 W	N 30 E	S 20 W	N 5 W					
Xb-9	35.3815	84.4749	N 52 E 22 SW		S 45 W	S 5 W	S 70 W	S 40 W					picture
Xb-10/PV1	35.1113	84.6902	N 73 E 29 S	N64 E 39 SW	S 28 W	S 5 W	S 10 W	S 13 W	S 32 W?	S 58 W	S 24 W	S 3 W	
Xb-11/PV3	35.835	84.6864	N 27 E 39 SE ot		S 40 E	S 43 E							
Xb-12/PV3.5	35.0829	84.6883	N 22 W 58 NE										3.5-1
Xb-13/Pv4	35.101	84.6952	N 43 E 33 S	N 17 E 29 E	S 27 W								
Xb-14/PV5	35.101	84.6982	N 57 E 32 S		S 23 W	S 23W	S 19 W	S 27 W					
Xb-15/PV6	35.0772	84.7031	N 68 E 36 SE										
Xb-16/PV7	35.0529	84.6758	N 48 E 4 SE ot		S 67 W	S 47 W	S 38 W	S 48 W					
Xb-17/PV8	35.0163	84.7013	N 43 E 37 SE ot										sample pv 8
Xb-18/PV9	35.0224	84.7123	N 14 E 27 SE	N 11 E 27 SE	N 88 E	N 77 E	N 74 E						
Xb-19/PV10	35.0114	84.724	N 19 E 48 SE		S 70 E ?	S 67 E ?	N 58 W	N 19 W					
Xb-20/TG1	34.9532	84.7429	N 22 W 33 NE										
Xb-21/TG2	34.948	84.7278	N 28 E 37 SE	N 37 E 27 SE	N 46 E	N 50 E	N 65 E	N 45 E	N 80 E				
Xb-22	35.4342	84.5855	N 55 E 37 SE		S 60 E	S 45 E	S 32 E						
Xb-23	35.2296	84.7412	N 22 3 15 NW		N 30 W	N 25 W							
Xb-24	35.2318	84.7408	N 42 E 32 SE										
XB-25	35.2537	84.7344	N 15 E 25 SE		S 30 E	S 40 E	S 15 E	S 25 E	N 80 E	S 34 E	N 84 E		
Xb-26	35.2843	84.7219	N 15 E 20 SE		S 25 E	S 50 E	S 35 E	N 50 W	S 33 E	S 55 E			
Xb-27	35.2843	84.6976	N 3 E 2 E		N 89 E	N 70 E	S 85 W	S 70 E	S 35 E				
Xb-28	35.3445	84.6677	N 20 E 24 SE		N 60 E	N 62 E	N 30 E	N 45 E					
Xb-29	35.7285	84.1528	N 63 16 E		S 6 W	S 11 E	S 45 E	S 18 E	S 18 W				
Xb-30	35.6786	84.2002	N 50 E 38 SE		N 60 W	S 85 E	S 89 E						
Xb-31	35.374	84.6476	N 37 E 9 SE		S 85 W	S 2 W	S 3 E	S 15 E					
Xb-32	35.3785	84.6044	N 43 E 23 NW		S 63 E	N 22 E	S 44 W	N 38 E					
Xb-33	35.4304	84.5648	N 31 E 82 NW		S 33 W	S 40 W							
Xb-34	35.5025	84.474	N 38 E 84 SE ot										
Xb-35	35.5282	84.4316	N 82 E 20 N		N 72 E	N 40 E							
Xb-36	35.5244	84.4357	N 18 E 14 NW		S 88 W	S 80 W	N 80 E						
Xb-37	35.5298	84.4293	N 43 E 15 SE		N 80 E	N 60 E	S 74 E						
Xb-38	35.5459	84.414	N 38 E 26 SE		S 5 W	S 45 E	S 50 E	S 55 E	S 15 E				
Xb-39	35.5989	84.3411	N 20 E 18 SE		S 22 E	N 23 E	S 20 E						
Xb-40	35.5859	84.3492	N 36 E 27 SE		S 54 E	S 52 E	S 22 E	N 57 E					
Xb-41	35.578	84.3657	N 43 E 22 NW		N 9 E	N 80 W	N 80 E						
Xb-42	35.5793	84.3714	N 38 E 17 SE		S 11 E	S 6 W	S 30 W	S 7 W					
Xb-43	35.7066	84.1755	N 55 E 18 E		N 30 W								
Xb-44	35.7045	84.1563	N 30 W 9 SW		N 70 E	N 35 E							
Xb-45	35.7354	84.1392	N 66 E 20 S		S 45 E	S 35 E							
Xb-46	35.7508	84.1238	N 51 29 S		S 60 E								
Xb-47	35.9068	83.9828	N 47 E 27 S		N 73 E	N 60 E	N 55 E						
Xb-48	35.869	84.0091	N 80 W 7 N		N 60 E	N 50 W	N 60 W	N 43 W	S 40 E	S 80 E			
Xb-49	35.9317	83.9482	N 59 E 34 S		S 60 E	S 15 W	S 65 E	S 55 E	S 20 W	S 10 E			
Xb-50	35.9012	83.9078	N 70 E 58 S		S 32 E	N 12 E	N 10 E	S 8 W					

Appendix II

Digital Field Notebook

Explanation of abbreviations used in Digital Field Notebook table.

Station No.	Station number recorded in field notes.
Quadrangle	Name of 7.5-minute quadrangle in which station lies.
Unit name	Name of map unit in which station lies.
Rock Type	Lithologic description.
Kind	What type of geologic feature was measured: B = bedding B(ot)= overturned bedding C = cleavage V = vein Fr = fracture Xb = cross bedding FA = fold axis FP = fault plane AP = Axial plane
S/T	Strike or trend of feature recorded in azimuth.
P/D	Plunge or Dip of feature.
Dir.	Plunge or Dip direction of feature.
Quaternary Unit Type	Subdivision of quaternary sediments.
Terrace Level	average elevation of quaternary terrace deposit
Comments	additional comments/descriptions.

Station No.	Quadrangle	Rock type	Unit name	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Quaternary Unit Type
1	Vonore	Tan, finely bedded siltstone/shale	Athens Sh.?	B	49	40	S																									
2	Vonore	Gray limestone, pitted surface , some calcite filled vugs		B	60	9	S																									
3	Tallassee		Quaternary																													Fluvial
4	Tallassee		Quaternary																													Fluvial
5	Tallassee		Quaternary																													Fluvial
6	Tallassee		Quaternary																													Fluvial
7	Tallassee	Thinly bedded limestone in stream, slightly folded		B	52	90		B	52	65	S																					
8	Vonore	Brick red sandstone thick to medium bedding	Bays?	B	60	27	S	C	66	60	N																					
9	Tallassee	Brick red sandstone	Bays?	B	66	60	N	B	55	35	N																					
10	Vonore																															
11	Vonore	Lt. gray limestone? Fine laminations	Copper Ridge?	B	50	64	S																									
12	Vonore	Dark gray limestone/dolostone	Knox																													
13	Vonore	Massive limestone/ dolomite																														
14	Vonore	Siltstone float																														
15	Vonore	Tan to slightly green siltstone/shale	Athens?	B	50	24	S																									
16	Vonore																															
17	Vonore	Limestone																														
18	Vonore	Tan to green siltstone		B	50	90																										
19	Vonore	Thinly bedded tan siltstone with some red mottling	Conasauga?	B	55	67	S																									
20	Vonore	Red-brown to gray-brown, thinly bedded siltstone/shale	Conasauga?	B	55	56	S																									
21	Vonore	Thinly bedded siltstone	Conasauga?	B	50	45	S	B	20	10	S	B	280	44	N																	
22	Vonore																															
23	Vonore	Thin-bedded red and tan siltstone/shale	Conasauga?	B	50	25	S	B	50	25	S	B	65	65	N																	
24	Vonore																															
25	Vonore	Green/brown tan thin-bedded shale	Conasauga?	B	40	43	S																									
26	Vonore																															
27	Vonore	Limestone with some finely laminated bedding	Pitted Knox?	B	58	55	S																									
28		Limestone	Knox	B	58	55	S																									
29	Vonore	Oolitic limestone	Chepultepec of Knox																													
30	Vonore		Quaternary																													
31	Vonore		Quaternary																													
32	Vonore	Limestone/dolostone dark gray	Knox	B	50	55	S																									
33	Vonore	Green and red shale	Sevier																													
34	Vonore																															
35	Vonore	Grey sandstone? Brown weathered surface, Siliciclastic limestone	Sevier	B	65	45	S																									
36	Vonore	Dark to medium gray quartz bearing limestone	Sevier	B	22	22	N																									

Station No.	Terrace level	Comments
1		
2		
3		Wandered across probable old terrace deposit. Some light tan soil in road 30% sand, probably high guess, on ridge which Leonard's map calls Grainger group, Lake is low enough to see old river boundaries and probably some of old flood plain.
4		Dark gray rock with red and tan 1mm size chert clasts, metagraywake or conglomerate but clasts in matrix are small, no discernable bedding
5		Relatively high, 2ft above water at present level, light colored sand at very surface but digging shows same brown subsurface soil color as all around. Mostly mud
6		Medium to fine grained sand deposit on north shore of island, Could be nothing but I have not seen anything like it on the south side of the island as I walked along the beach
7		
8		Slight cleavage discontinuous, in thinner layers
9		
10		Walking along shore near Athens Blockhouse, float of chert bearing rock, surrounded by red brown soil, Maybe limestone or dolomite but has a quartzite look, hardness too low though, Doesn't scratch hammer
11		Along shore below Blockhouse parking area, Red soil high clay content ,sticks to boots, Tan-orange when exposed, Rounded cobbles of quartzite up to 8 cm across
12		Maybe slightly different from station 11
13		Somewhat pitted, resembles Meagher limestone in Montana
14		pictures 1.3-1.4 are of buried drain pipe
15		Somewhat folded internally
16		Lagoon type area Surficial deposits have changed from containing predominantly siltstone chips and the occasional cobble to the reddish hue I saw near the Athens Blockhouse shoreline. Sticks to your boots. Cobbles have increased so there is almost a cob
17		highly weathered, no clear bedding
18		
19		Between station 19 and 20. Red sticks to the boots soil of limestone for about 10 meters and then come back into thin bedded siltstone/shale
20		Shoreline has cobbles to sand size particles of some conglomerate and some quartzite
21		Some bed thickening up to 10 cm thick, Bedding changes rapidly, Small antiform
22		Above Folds, Red Brown soil sticks to boots. Am starting to associate with Knox. Strange?
23		
24		Highly folded picture1.3-1.5, Picture 1.6 at end of train barge jetty thing typical of red soil
25		
26		Sandy soil, fine grained sand with gravel surrounding it
27		
28		
29		Cobbly shoreline, Bluff face of shore is picture 1.7, Pebble to small cobbles in soil, Mostly limestone/dolostone, Poorly sorted cobbles 1 ft> of quarter, sandstone, conglomerate, and carbonate along shore extends for 10 to 15 meters, along shore in both dire
30		Picture 1.8 Soil big clasts are 2-3 cm, Chert/limestone
31		Fine sand again
32		
33		No good bedding, might be dipping north?
34		Red brown silty consisting soil with trace amounts of quartz sands, Contains many chert cobbles up to 10 cm in size but mostly pebbles of 2-3cm in size
35		Has clasts of quartz in it. Laminations which may be cross beds or may be just laminations
36		

Station No.	Quadrangle	Rock type	Unit name	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Quaternary Unit Type
37	Vonore	Tan shale/siltstone chips	Sevier																													
38	Vonore	Grey limestone	Sevier	B	56	35	S	B	70	25	S																					
39	Vonore	Dark red sand/siltstone	Bays?	B	60	20-30	S																									
40	Vonore	Brick red sandstone	Bays?	B	85	35	S																									
41	Vonore	Brick red sandstone	Bays	B	285	25	S																									
42	Vonore	Brick red sandstone	Bays	B	89	13	S																									
43	Vonore	Brick red sandstone	Bays	B	30	13	S																									
44	Vonore	Brick red sandstone	Bays	B	330	2	S																									
45	Vonore	Brick red sandstone	Bays	B	70	22	S																									
46	Vonore	Brick red sandstone	Bays	B	55	40	S																									
47	Tallassee	Brick red sandstone	Bays	B	280	5	S																									
48	Tallassee	Brick red sandstone	Bays	B	70	18	S																									
49	Tallassee	Brick red sandstone	Bays	B	80	15	S																									
50	Tallassee	Red siltstone/ very fine grained sandstone	Bays																													
51	Vonore	Finely bedded siltstone	Bays	B	325	20	S																									
52	Vonore	Tan to slightly green shale	Athens?	B	50	40	S	Fr	50	55	N																					
53	Vonore	Tan shale	Athens	B	20	75	S																									
54	Vonore	Tan shale	Athens	B	50	25	S																									
55	Vonore																															
56	Vonore	Tan shale	Athens	FA	230	18	S																									
57	Vonore	Thick bedded shale with soft sediment deformation	Athens																													
58	Vonore	Grey/tan calcareous shale	Athens	B	40	30	S																									
59	Vonore	Thinly bedded shale	Athens	B	50	60	S																									
60	Vonore	Grey calcareous shale	Chapman Ridge	B	49	30	S																									
61	Tallassee	Grey siliciclastic limestone or calcareous siltstone	Chapman Ridge																													
62	Vonore	Tan shaly/siltstone	Chapman Ridge	B	70	47	S																									
63	Vonore	Grey calcareous siltstone/sandstone	Sevier?	B	40	42	S																									
64	Vonore	Grey medium to thick bedded cross bedded calcareous sandstone		B	50	27	S																									
65	Vonore	Grey calcareous sandstone with some calcite veins	Sevier	B	55	26	S	V	273	87	N																					
66	Vonore																															
67	Vonore	Grey fine grained sandstone/siltstone	Sevier	B	60	40	S																									
68	Vonore		Quaternary																													
69	Vonore	Grey/tan siltstone/limestone	Sevier	B	60	26	E																									
70	Vonore	Tan grey calcareous thinly bedded siltstone	Sevier	B	55	27	S																									
71	Vonore	Massively bedded calcareous siltstone/sandstone with more resistant ribbons of what appears to be more limestone impregnated with quartz sand	Sevier	B	50	32	S																									
72	Vonore	Brown/grey calcareous sandstone with rounded chert pebble	Sevier	B	50	32	S																									
73	Vonore		Quaternary																													
74	Vonore	Tan soil shale chips																														
75	Vonore	Calcareous sandstone	Sevier	B	57	36	S																									
76	Vonore	Tan/green siltstone/shale		B	53	44	S																									
77	Vonore	Calcareous fine grained sandstone	Sevier	B	45	26	S																									
78	Vonore	Tan shale chips																														

Station No.	Terrace level	Comments
37		No outcrop
38		Biery has this outcrop labeled as Bays on his map but it seems to be a gray limestone and not the brick red sandstone that is distinctive Bays. Good bedding is tough to find on the outcrop but measurement is consistent with general trend of outcrop
39		Can't get dip measurement
40		
41		Still Bays, everything on Bierys map checks out between here and Station 40, Except for the fault
42		
43		
44		
45		
46		on deforested hill, some cleavage
47		
48		
49		
50		
51		
52		Fracture pattern normal to bedding
53		
54		
55		Until now chippy shale on beach, Now quartzite cobbles appear,10 cm and down in size
56		Small synform mirroring larger structure, Picture 1.12
57		Picture 1.13, Faulting or soft sediment deformation
58		
59		
60		
61		
62		
63		No clue what formation, Fine, laminated almost looks like cross bedding, Nearby, small wall under overhang?, made of same rock, manmade?
64		
65		
66		maybe some sort of slump feature, probably not more than 100 years old if it is judging from the trees, soil here is tan mostly, not as sticky as red soil in other location
67		In small clear cut, quartz pebbles to cobbles in soil, poorly sorted, up to 7 cm in diameter, with up to 2mm weathering rinds
68		
69		
70		
71		
72		not many chert pebbles but distinctive
73		Red clay on another clear cut, quartzite cobbles up to 7 cm in diameter, rounded poorly sorted some arkose looking cobbles Red soil
74		no rock outcrop but some lithologic contact between station 73 and 74
75		Breaks like a quartzite, No ribbons, Wavy Beds, Goes from being rather fissile to massively (not really right here), Has bedding but does not stand out of the outcrop face
76		
77		
78		

Station No.	Quadrangle	Rock type	Unit name	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Quaternary Unit Type
79	Vonore	Grey medium bed thickness calcareous sandstone	Sevier	B	55	21	S																									
80	Vonore	Lens of sandstone in siltstone matrix	Bacon Bend	B	60	18	S																									
81	Vonore	Red siltstone/ very fine grained sandstone	Bays	B	48	40	S																									
82	Vonore	Finely laminated red shale	Bacon Bend/ Bays	B	50	25	S																									
83	Vonore	Tan/grey thinly bedded shale	Sevier?	B	60	45	S																									
84	Vonore		Bacon Bend/ Bays	B	50	36	S																									
85	Vonore	Grey calcareous sandstone	Bacon Bend																													
86	Vonore	Medium bedded calcareous siltstone	Sevier	B	60	29	S																									
87	Vonore		Quaternary																													Fluvial
88	Vonore		Quaternary																													Fluvial
89	Vonore	Red siltstone	Bays	B	65	49	S																									
90	Vonore	Red siltstone	Bays	B	43	22	E																									
91	Vonore	Red siltstone	Bays	B	60	47	S																									
92	Vonore	Red siltstone	Bays	B	40	75	N	B	52	57	S	B	52	57	S	B	47	37	N	B	45	40	S									
93	Vonore	Red siltstone	Bays	FP	45	32	S																									
94	Vonore		Bays	B	40	50	S																									
95	Vonore	Massive thick bedded sandstone	Bays	B	30	5	W																									
96	Vonore		Bays																													
97	Vonore	Siltstone	Bays	B	59	17	S																									
98	Vonore	Siltstone	Bays	B	50	22	S																									
99	Vonore	Siltstone	Bays	B	54	41	S																									
100	Vonore	Calcareous sandstone/siltstone	Bays	B	66	38	S																									
101	Vonore	Calcareous siltstone	Bays																													
102	Vonore		Quaternary																													
103	Vonore	Calcareous sandstone	Sevier	B	46	27	S																									
104	Vonore		Quaternary	B	52	27	S																									
105	Vonore	Calcareous siltstone interbedded with red and yellow shale	Sevier	Fr	59	65	W	Fr	77																							
106	Vonore		Sevier	AP	320	90		FA	150	40	SE	FP	80	48	S																	
107	Vonore	Tan and red interbedded shale and calcareous siltstone	Sevier	B	54	23	E	FA	244	9	SW	AP	50	40	SE	FA	227	16	E	AP	37	32	SE	FA	70	43	NE	FA	102	88	S	
108	Vonore	Deformed yellow/brown thinly bedded shale above gray medium bedded mudstone	Sevier	B	54	47	S																									
109	Vonore	Grey calcareous siltstone	Sevier	B	55	29	S																									
110	Vonore	Cross bedded fine grained sandstone	Chota?	B	47	34	S	Xb	66	50	SE																					
111	Vonore	Grey crossbedded fine-grained sandstone	Sevier	B	51	54	SE																									
112	Vonore	Grey siltstone	Sevier	B	52	29	S																									
113	Vonore	Calcareous silt/sandstone	Bacon Bend	B	52	29	S																									
114	Vonore	Grey calcareous Silt/sandstone	Sevier	B	49	26	SE																									
115	Vonore	siltstone	Bays	B	44	27	SE																									
116	Vonore	Grey silt/sandstone	Sevier	B	54	26	SE																									
117	Vonore	Grey siltstone	Sevier	B	48	24	SE	Xb	290	14	NE																					
118	Vonore	Grey calcareous siltstone	Sevier	B	40	29	SE																									
119	Vonore	Grey thinly bedded calcareous siltstone	Sevier	B	33	32	SE																									

Station No.	Terrace level	Comments
79		Nice rounded quartz grains, grains are brownish/tan in color, some soft sediment structures here, Picture 1.15 Ripple marks on the underside of beds, Ribbons appear 10 to 15 ft below picture
80		Lenses weather out leaving voids, Appears to be Neuman's Bacon Bend member of the Sevier Formation
81		
82		Picture 1.16 collapse structure at top of Bacon Bend member, Contact between bays and Sevier at fence
83		
84		Contact between Bays and Bacon Bend Member of the Sevier Formation bulldozed side of road
85		Contact is reasonably easy to follow as it is just to the south of the ridge crest and undulate slightly depending on amount of erosion
86		Just stratigraphically below contact
87	shore	Shore, Big Cobbles, up to 18 cm in diameter, of slightly arkosic sandstone/quartzite pretty well rounded gray/brown sand
88	shore	Red to tan extremely solid mud in Sevier formation, Rounded tan shale pebbles mark this as shaly Sevier, End of solid mud and beginning of soft mud may be indicative of Bays/Sevier contact, Not really, streams discharge the mud that I thought was a contact
89		
90		Hard clay is characteristic of soil development on Bays too but, can tell where soil survey made distinctions
91		Soil development on bend between stations 90 and 91 is mainly and orange-yellow matrix with sandstone and quartzite cobbles, occasionally even the Wilhite formation slate.
92		
93		Small scale fault in Bays, offset 1 to 1.5 feet
94		
95		
96		Large slump of Bays, Less than 100 years old judging from the amount of exposure and the nearly fallen trees
97		
98		
99		
100		
101		Picture 1.17,Bays contact with Sevier formation, Picture 1.18 , Cliffs of Calcareous sandstone of Sevier
102		All stream mouths have cobble size deposits in them, with cobbles of quartzite, conglomerate and sandstone
103		
104		Terrace deposits on Sevier, Hammer is 28 cm long Picture 1.20
105		
106		Blind Thrust fault with fault bend fold, Picture 1.21Vonore
107		Highly folded siltstone with some shale , all red, Picture 1.22 Fold (FA 22 16 E) , Picture 1.23, Rip up clasts, Clasts are sandy and browner than surrounding mudstone, small folds in shale to the north, red siltstone on either side
108		Two green line on map show approximate boundaries of deformed zone
109		
110		Contact between Chota/Holston and Sevier?, Crossbeds weather out more prominently, Picture 1.24
111		
112		
113		
114		
115		
116		
117		
118		
119		

Station No.	Quadrangle	Rock type	Unit name	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Quaternary Unit Type
120	Tallassee	Interbedded tan siltstone and gray calcareous siltstone/sandstone	Chapman Ridge	B	45	42	S	FA	130	60	SE	FA 1	210	4	S	B1	340	27	W	B1	285	65	W	B1	80	28	S	B1	45	32	S	
120.1		*Station 120 - Continued*		FA 2	210	20	SE	AP2	35	40	S	B2 (ot)	50	66	S	B2	55	26	S	FA 3	205	23	S	B3	60	30	S	B3	0	38	W	
121	Tallassee	Brick red sandstone	Bays	B	36	9	S	C	20	77	E																					
122	Tallassee	Silt/sandstone	Bays	B	335	10	S																									
123	Tallassee	Fine grained sandstone, .5 foot thick bedding	Bays	B	335	10	S																									
124	Tallassee	Fine grained sandstone	Bays	B	355	12	E																									
125	Tallassee	Sandstone	Bays	B	50	6	E																									
126	Tallassee	Sandstone	Bays	B	88	22	S																									
127	Tallassee	Fine grained sandstone	Bays	B	75	21	S																									
128	Tallassee	Fine grained sandstone	Bays	B	45	13	S	Fr	40	75	N																					
129	Tallassee	Calcareous siltstone	Sevier?	B	89	9	S																									
130	Tallassee	Grey calcareous Silt/sandstone	Sevier	B	325	5	S																									
131	Tallassee	Cross bedded fine grained sandstone	Sevier	B	348	17	E																									
132	Tallassee	Grey thick bedded silt/sandstone	Sevier	B	20	5	E																									
133	Tallassee	Calcareous sandstone/siltstone	Sevier	B	65	6	S																									
134	Tallassee	Grey calcareous sandstone/siltstone	Sevier	B	0	7	E																									
135	Tallassee	Sandstone	Bays	B	340	5	E																									
136	Tallassee	Sandstone	Bays	B	285	20	N																									
137	Tallassee	Sandstone	Bays/Sevier	B	280	19	N																									
138	Tallassee	Bacon Bend	Sevier, Bacon Bend	B	271	11	N																									
139	Tallassee	Grey crossbedded fine grained sandstone	Sevier	B	65	4	N																									
140	Tallassee		Sevier	B	80	4	N																									
141	Tallassee	Calcareous siltstone	Sevier	B	51	40	N																									
142	Tallassee	Bacon Bend	Bays/Sevier	B	271	15	N																									
143	Tallassee	Bacon Bend	Bays/Sevier	B	40	15	N																									
144	Tallassee		Bays	B	60	34	N																									
145	Tallassee		Bays	B	60	36	N																									
146	Tallassee	tan/green shale float		Float																												
147	Tallassee		Bays	B	340	22	E																									
148	Tallassee	Fine grained calcareous sandstone	Bays	B	20	21	E																									
149	Tallassee		Bays	B	340	22	E																									
150	Tallassee		Bays	B	30	22	N																									
151	Tallassee		Bays	B	80	15	N																									
152	Tallassee		Bays	B	10	55	E																									
153	Tallassee		Bays	B	310	48	N																									
154	Tallassee		Bays	B	90	17	N																									
155	Tallassee		Bays	B	305	10	N																									
156	Tallassee		Bays	B	325	14	N																									
157	Tallassee		Bays	B	340	15	E																									
158	Tallassee		Bays	B	305	25	E																									
159	Tallassee		Bays	B	15	35	E	C	73	80	N																					
160	Tallassee	Thinly bedded siltstone	Bays	B	15	20	E																									
161	Tallassee	Thickly bedded siltstone	Bays	B	15	24	E																									
162	Tallassee		Bays	B	0	12	E																									
163	Tallassee		Bays	B	30	12	W																									
164	Tallassee		Bays	B	280	22	N																									
165	Tallassee	Grey fossiliferous limestone, thin to medium bedding	Sevier?	B	45	35	S																									
166	Tallassee	Cross bedded gray calcareous medium grained sandstone float	Sevier?	Float																												
167		Tan calcareous siltstone	Sevier?	B	50	35	S																									
168	Tallassee	Mudstone	Sevier	B	60	35	S																									
169	Tallassee	Grey mudstone	Sevier	B	60	35	S	B	35	45	S	B	35	45	S	B	35	45	S	B	35	45	S	B	35	45	S					
170	Tallassee	Thinly bedded tan siltstone interbedded with grey calc. fine to med. grained sandstone	Sevier	B	51	29	E																									
171	Tallassee	Thinly bedded calcareous siltstone	Bacon Bend	B	50	15	S																									

Station No.	Terrace level	Comments
120		Picture 2.1 ,Upper face above terrace, Interbedded thin to medium bedding thickness siltstone, may be folded may be soft sediment deformation, Pencil may point down a fold axis, Picture 2.2, Upper face of outcrop above terrace, southernmost good exposure
120.1		
121		Some Cleavage, Picture 2.4 typical cleavage plane, picture taken towards NE
122		
123		
124		
125		
126		
127		
128		
129		Picture 2.6, Wavy bedding, Contact between Bays and Sevier 20 feet above station location
130		
131		Picture 2.7
132		
133		
134		
135		Might just cap this ridge
136		May be near Sevier
137		Contact between Sevier and Bays
138		Contact just uphill ten Feet
139		
140		
141		
142		Bays to top of ridge, Bays down to river
143		Collapse structure or Rip up clasts, Picture2.8
144		
145		
146		
147		
148		Stupid Gradational Contact
149		
150		
151		
152		
153		
154		
155		
156		
157		
158		
159		
160		
161		
162		
163		Dips opposite way on either side of station
164		
165		Crinoid stems, some gastropods?, some thin sand layers, sparry in some places, micritic in others,
166		
167		
168		has small lenses of calcareous siltstone
169		Some small scale ,cm size, folding and rock is really crapped up but to much covered to tell what's going on
170		
171		Soft sediment deformation

Station No.	Quadrangle	Rock type	Unit name	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Quaternary Unit Type
172	Tallassee		Bacon Bend	B																												
173	Tallassee		Bacon Bend	B	50	26	S																									
174	Tallassee	Red siltstone float	Bays	Float																												
175	Tallassee	Siltstone	Bays	B	20	10	W	C	20	84	S																					
176	Tallassee	Siltstone	Bays	B	49	55	N	C	59	75	S																					
177	Tallassee	Siltstone	Bays	B	55	1	S	C	58	84	N																					
178	Tallassee	Siltstone/sandstone	Bays	B	300	10	S	C	50	84	N																					
179	Tallassee	Fine grained calcareous sandstone	Bays	B	61	15	S																									
180	Tallassee	Fine grained calcareous sandstone	Bays	B	55	15	S																									
181	Tallassee	Grey calcareous medium thickness crossbedded sandstone	Sevier	B	50	23	S																									
182	Tallassee	Grey sandstone	Sevier	B	15	60	N	B	42	6	N	FA	45	7	NE																	
183	Tallassee	Cross bedded gray calcareous medium grained sandstone	Sevier	B	40	43	S																									
184	Tallassee	Calcareous siltstone/sandstone thinly bedded	Sevier	B	45	22	S	B	43	22	S																					
185	Tallassee	Cross bedded gray calcareous fine/medium grained sandstone	Sevier	B	51	17	N																									
186	Tallassee	Cross bedded gray calcareous fine/medium grained sandstone	Sevier	B	51	44	S																									
187	Tallassee	Fold train	Sevier	B	40	26	N	FA	240	20	SW	AP	60	52	NE	FA	255	15	S	AP	60	52	N	FA	240	15	E	AP	60	55	N	
187.1		*Station 187 - Continued*		V	60	5	NE	V	330	5	N	FA	60	7	NE	AP	60	62	N	FA	75	15	E	AP	70	50	N					
188	Tallassee	Calcareous siltstone	Sevier	B	50	45	S																									
189	Tallassee	Calcareous siltstone, tan/gray	Sevier	B	55	39	S																									
190	Tallassee	Medium bedded interbedded calcareous siltstone/ fine grained sandstone	Sevier	B	58	41	S																									
191	Tallassee	Calcareous siltstone	Sevier	B	65	22	N	B	82	37	S	FA	55	6	NE																	
192	Tallassee	Cross bedded sandstone	Sevier	B	90	18	N																									
193	Tallassee	Fine grained calcareous sandstone	Sevier	B	54	19	S	B	61	25	S	FA	70	6	NE	B	21	35	N	FA	196	16	S	FA	258	12	S	FA	248	6	S	
193.1		*Station 193 - Continued*		B	68	25	S	B	58	15	N	B	90	40	NE																	
194	Tallassee	Interbedded siltstone and gray Mudstone	Sevier	B	65	77	S	B	56	72	N	AP	65	71	NE	FA	56	5	E	FA	65	2	E	AP	65	0						
195	Tallassee	Fine grained thin to medium bedded sandstone	Sevier	B	55	42	S																									
196	Vonore	Cross bedded fine grained sandstone	Sevier	B	61	44	S																									
197	Vonore	Thinly bedded calcareous siltstone	Sevier	B	52	47	S																									
198	Vonore	massively bedded gray calcareous siltstone	Sevier	B	46	27	S																									
199	Vonore	massively bedded gray sparry limestone with coarse sand grains	Chota?	B	65	27	S																									
200	Vonore	Fine grained gray calcareous siltstone	Sevier/ Chota	B	57	57	S																									
201	Vonore		Quaternary																													Fluvial
202	Vonore	Tan thinly bedded mudstone	Chapman Ridge	B	54	36	S																									
203	Vonore	Dark Grey calcareous siltstone	Chapman Ridge	B	50	42	S																									
204	Vonore	Tan and brown shale / siltstone	Chapman Ridge	B	50	37	S	Fr	280	69	N	Fr	320	90																		
205	Vonore	Tan/green shale	Chapman Ridge	B	32	58	S	FA	50	15	N	AP	60	85	S																	
206	Vonore	Dark grey thinly bedded calcareous siltstone	Chapman Ridge	B	50	38	S																									
207	Vonore	Interbedded Mudstone and medium bedded calcareous/ hematite sandstone	Chapman Ridge	B	40	42	S																									
208	Vonore	Grey/tan thin/med. bedded calc. fine grained silt/sandstone	Chapman Ridge	B	45	45	S	B	40	37	S	FA	37	10	NE	AP	37	20	S													
209	Vonore	Thinly bedded calcareous siltstone	Chapman Ridge	B	47	37	SE																									

Station No.	Terrace level	Comments
172		Picture 2.10, typical Bacon Bend member of the Sevier with soft sediment Badinage, Grey pods are more calcareous, red pods have more hematite cement doesn't fizz very well
173		picture 2.11 soft sediment deformation, some layers contain brachs
174		
175		
176		Picture 2.12, cleavage/fracture in bays siltstone
177		Folded cleavage, Perpendicular to bedding , (Bedding N 51 E 71 N, Cleavage N 50 E 52 S) (Bedding N 15 E 26 N, Cleavage N 55 E 71 S)
178		
179		
180		Bays gets more cleavage as it gets siltier
181		
182		Small scale folding? Too little outcrop at this location to tell what's going on, Big outcrop further west
183		
184		
185		
186		
187		Picture 2.12-2.13, folds at south west,2.14-2.15 folds to north 2.17, hinge collapse, Hammer is along folds axis N to left multiple folds in fold train, listed with fold axis first and pertinent information about that particular fold after, ex. Fold Axis
187.1		
188		
189		
190		Storm event? Clasts and fossils, crinoids, brachiopods
191		folds in Sevier vergence changes from south
192		
193		Picture 2.18, on west side of road, Jen is pointing towards North
193.1		
194		Area of a lot of folding, some caves where shale has weathered out between massive sandstones, Highly folded and cleaved shales, Picture 2.22-2.23 in cave, 2.24 small scale fold and hinge collapse
195		No longer highly folded, ripple marks on face
196		
197		
198		
199		Pinky looking in spots
200		Contact between Chota and Sevier
201	at water level	Shoreline lined with cobble sized 8 cm and down composed of tan sandstone/quartz and some conglomerate poorly sorted soil has 5 Y/R 5/6 light brown color
202		
203		Bedding 2in thick to tan/orange shale after 10ft/ 3m
204		maybe small, centimeters, of offset but hard to tell
205		Picture 3.2 Fold, 3.3 down dip, 3.4 normal to outcrop face, picture are of red material in shalier tan/buff colored beds of more siltstone like consistency, these features found periodically throughout the shalier units in this area, they do not offset
206		
207		Sandstone feels too light/ low density, may be closer to siltstone, subrounded grains of quartz with hematite cement/ near by thinly bedded calcareous fossiliferous siltstone, Bryozoans? Gastropods?
208		Bedding has become slightly thicker and more folded than previous beds, Folds verge to Northwest, plunge changes slightly but trend stays the same for all folds in this area
209		

Station No.	Quadrangle	Rock type	Unit name	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Quaternary Unit Type
210	Vonore	Tan calcareous siltstone	Chapman Ridge	B	47	32	S																									
211	Vonore	Grey to tan thinly bedded shale	Athens	B	33	78	S																									
212	Vonore	Interbedded tan medium thick siltstone and thin shale	Athens	B	60	30	S																									
213	Vonore	Grey/tan shale	Athens	B	67	57	S																									Fluvial
214	Vonore	Tan/brown thinly bedded shale	Athens	B	65	52																										
215	Vonore	Gray dark to lightly banded mudstone	Athens	B	55	22	S	C	40	53	S																					
216	Vonore	Grey silty mudstone	Athens	B	310	15	N																									
217	Vonore		Quaternary																													Fluvial
185	Vonore	Grey thin bedded mudstone	Athens	B	50	50	S	B	40	36	E																					
219	Vonore		Quaternary																													Fluvial
220	Vonore	Mudstone	Athens	B	25	27	N																									
221	Vonore	Thinly bedded mudstone	Athens	B	33	39	S	B	12	26	S	B	60	53	N	B	75	6	N	FA	40	14	E	AP	40	85	S					
222	Vonore																															
223	Vonore	Thinly bedded limestone, silty	Athens?	B	57	90																										
224	Vonore		Quaternary																													Fluvial
225	Vonore	Dark gray limestone and calcareous mudstone	Athens	B	30	53	S	B	65	35	S																					
226	Vonore	Grey calcareous medium to thinly bedded shale	Athens	B	65	19	S																									
222	Vonore	Grey calcareous medium to thinly bedded shale	Athens	B	60	80	N	B	89	70	N	B	315	64	E																	
228	Vonore	Calcareous shale	Athens	B	60	19	S																									
229	Vonore	Calcareous shale	Athens	B	55	64	E																									
230	Vonore	Tan thinly to medium bedded silty shale	Athens	B	50	60	S																									
231	Vonore	Tan grey shale	Athens	B	52	56	S																									
232	Vonore	Thin limestone/calcareous shale	Athens	B	70	43	S																									
233	Vonore	Grey calcareous medium to thinly bedded shale	Athens	B	80	36	S																									
234	Vonore	Grey calcareous medium to thinly bedded shale	Athens	B	276	8	N																									
235	Vonore	Tan calcareous thinly bedded shale	Athens	B	64	53	S																									
236	Vonore	Tan calcareous shale	Athens	B	59	84	S																									
237	Vonore		Quaternary																													Fluvial
238	Vonore		Quaternary																													Fluvial
239	Vonore	Finely laminated medium gray dolostone	Knox	B	43	34	S	B	54	24	S																					
240	Vonore	Thinly bedded dark gray limestone with frosted quartz grains	Knox	B	72	42	S																									
241	Vonore	Dark gray limestone with black chert nodules	Knox	B	50	23	S																									
242	Vonore	Light gray with tan mottling limestone	Knox	B	42	29	S																									
243	Vonore		Quaternary																													Fluvial
244	Vonore	Dark grey dolostone	Knox	B	60	32	S																									
245	Vonore	Dark gray thick bedded limestone	Knox	B	49	19	S																									
246	Vonore	Grey/tan thinly bedded calcareous shale	Athens	B	56	9	S																									

Station No.	Terrace level	Comments
210		
211		Waviness in bedding, change in dip from 60 se to 70 NW but no clear fold hinge
212		
213		soil is colored close to 10 Y/R 6/6, consists of poorly sorted Dark yellow well rounded cobbles some brown, up to 8cm in length, mostly 50/50 concentration with clay, quartzite/sandstone, no weathering rind, around side of peninsula, many more cobble poorly
214		Dark Yellowish brown according to color chart
215		Dark bands appear to be siltier, cleavage is discontinuous
216		Yes, west
217		Soil here is harder 10Y/R 6/6 or as close to that as chart gets, matrix supported some cobbles but mostly pebble sized, all well rounded with red weathering, no rind, mostly sandstone/quartzite cobble 6cm across or less
185		
219		Tan Yellow sandstone cobbles, big ones 30 cm across some larger, poorly sorted weathering rinds only apparent on some rock Bigger rocks seem to be capping these two promontories
220		Good folds but need boat to get to them
221		Folded with some cleavage visible
222		Soil color has changed to brown, lithology change?
223		Picture 3.7, Just north thick bedded calcareous mudstone
224		Soil color not quite so red, more brown out of calcareous rich unit? Moderate Brown 5 Y/R 3/4 has some silt, shiny sticks together well when clumped, few small <6cm cobbles, friable, red interior when broken 2-3 mm weathering rind well rounded, matrix supported
225		some minor waviness/folding, generally thinly bedded to medium, very distinct concoidal looking fracture pattern soft sediment deformation? Picture 3.8 Typical soil profile, picture 3.9
226		
222		Folded
228		
229		
230		
231		
232		picture
233		
234		
235		
236		
237		Berm, Soil 5Y/R 3/4 moderate brown a little red, limestone float mixed with quartzite sandstone cobbles soil has enough sand component that it will not stay in clumps cobble of 10-12 cm across and down of quartzite, rounded to subrounded, limestone Subrounded
238		soil color mainly more red to the 5Y/R moderate brown, higher concentration of big cobbles 15% of total beach lack of limestone
239		little sand poor fizzier, resembles Meagher, dark banding is slightly more resistant to weathering than surrounding rock
240		some laminations, Light gray layer with well rounded frosted quartz grains, appear as dark spots on fresh face, light colored on weathered face
241		
242		might be contact between blockhouse as there is no more outcrop along shoreline
243	river	Sandy Clay and quartz gravel, limestone, some chert color 10 Y/R 5/4 moderate yellowish brown probably due to location downwind on lake
244		Sparry, almost quartzite in appearance, hard to tell bedding
245		Some fine laminations
246		

Station No.	Quadrangle	Rock type	Unit name	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Quaternary Unit Type
247	Vonore	Tan/brown thinly bedded siltstone/silty mudstone	Athens	B	60	22	S																					
248	Vonore	Tan/brown thinly bedded siltstone/silty mudstone	Athens	B	74	34	N	FA	34	14	NE	B	13	44	S	AP	34	78	N									
249	Vonore	Calcareous sandstone/sandy limestone w/	Chapman Ridge	B	45	32	S																					
250	Vonore	Red and tan shale	Chapman Ridge	B	40	49	S																					
251	Vonore	Shale float	Chapman Ridge																									
252	Vonore	Thinly bedded sandy shale	Chapman Ridge	B	27	45	N	B	33	37	S																	
253	Vonore	Loosely consolidated tan sandstone	Chapman Ridge	B	54	49	S																					
254	Vonore	Tan calcareous siltstone	Chapman Ridge	B	55	30	S																					
255	Vonore	Tan calcareous thinly bedded siltstone with some fine grained quartz	Sevier	B	45	30	S																					
256	Vonore	Light gray sparry limestone with dark laminations of very fine grained qtz sand	Sevier	B	55	25	S																					
257	Vonore	Interbedded sandstone and silty shale	Sevier	B	60	14	S																					
258	Vonore	Tan/grey/red/brown calcareous siltstone	Sevier	B	45	20	S																					
259	Vonore	Grey calcareous siltstone with soft sediment deformation	Bacon Bend																									
260	Vonore	Brick red medium to thick bedded calcareous siltstone	Bays	B	14	10	SE	Fr	45	87	N																	
261	Vonore	Tan/green sandy shale	Sevier	B	50	10	SE																					
262	Vonore	Tan calcareous siltstone/ shale	Sevier	B	35	24	SE																					
263	Vonore	Red and grey poorly cemented sandstone	Sevier	B	59	7	S																					
264	Vonore	Massive gray sparry limestone with dark brown qtz sand laminations	Sevier	B	60	33	S																					
265	Vonore	Calcareous siltstone/fine sandstone	Sevier	B	65	30	S																					
266	Vonore	Tan and brown shale saprolite	Sevier	B	59	50	S																					
267	Vonore		Quaternary																									
268	Vonore	Tan thinly to medium bedded silty shale	Chota	B	55	45	S																					
269	Vonore	Tan shale/siltstone	Chapman Ridge	B	45	44	S																					
270	Vonore	Grey calcareous sandstone with frosted quartz grains	Chota?	B	38	32	S																					
271	Vonore	Thinly bedded tan calcareous siltstone	Sevier	B	60	50	S																					
272	Vonore	Thick bedded calcareous siltstone	Sevier	B	55	43	S																					
273	Vonore	Tan shale with some siltstone and fossils	Sevier	B	54	30	S																					
274	Vonore	Tan thinly bedded shale	Sevier	B	50	35	S																					
275	Vonore	Calcareous mudstone with soft sediment deformation	Bacon Bend																									
276	Vonore	Dark gray calcareous fine grained sandstone with some poor crossbeds	Bays	B	56	34	S																					
277	Vonore	Thinly bedded and laminated calcareous mudstone	Bays?	B	43	23	S																					
278	Vonore	Brick red medium to thick bedded calcareous siltstone	Bays	B	37	13	S																					
279	Vonore	Gray calcareous fine grained sandstone	Bays	B	35	24	S																					
280	Vonore	Thinly bedded calcareous shale interbedded with gray calcareous siltstone	Sevier?	B	31	26	S																					
281	Vonore	Red/grey thinly bedded calcareous siltstone	Bays	B	89	25	N																					
282	Vonore	Brick red medium to thick bedded calcareous siltstone	Bays	B	47	40	S																					
283	Vonore	Red medium bedded calcareous fine grained sandstone	Bays	B	50	24	S																					
284	Vonore	Red siltstone/sandstone	Bays	B	65	16	S																					
285	Vonore	Red siltstone/sandstone	Bays	B	50	15	S																					
286	Vonore	Tan thinly bedded silty mudstone	Sevier	B	59	23	S																					
287	Vonore		Quaternary																									
288	Vonore	Tan and gray calcareous sandstone with interbedded shale	Sevier	B	55	37	S																					
289	Vonore	Rusty brown/orange poorly cemented fine/medium grained sandstone	Sevier	B	62	26	S																					

Station No.	Terrace level	Comments
247		
248		Noncylindrical folding along available outcrop
249		1mm rounded quartz grains
250		
251		chips in tree fall
252		bedding in old dirt road
253		
254		
255		
256		some gastropods in float
257		poorly cemented sandstone, hematite? With some 12 cm thick tan silty/ fine sand shale
258		
259		Picture 3.10, pencil is along strike
260		color is probably 10R 4/4 near grayish red, dark reddish brown and moderate reddish brown
261		
262		
263		
264		some fossils gastropods and crinoids
265		
266		
267		rather sandy red brown somewhat clayey soil but with good amount of sand
268		probably crossed contact between Chota and Athens at house, color change in soil from red Chota to tan Athens
269		
270		maybe crossbedded
271		
272		
273		bryozoans, gastropods, limestone pod underneath
274		
275		has many limestone cobble like features, bedding is not clear form this outcrop
276		
277		
278		
279		
280		
281		
282		
283		fossil hash has fan shaped characteristics, pictures 3.12-3.13 black king snake on branch
284		
285		No terrace deposits, all residuum of Bays
286		
287		Hilltop is residuum as far down as I can dig and also in a tree fall
288		
289		

Station No.	Quadrangle	Rock type	Unit name	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Quaternary Unit Type
290	Vonore	Massive gray sparry limestone with tan qtz sand laminations	Sevier	B	35	20	S																					
291	Vonore	Phaneritic limestone with frosted quartz grains	Chota?	B	46	24	S																					
292	Vonore	tan shale	Sevier?	B	37	27	S																					
293	Vonore	Thinly bedded light gray calcareous siltstone	Sevier?	B	75	24	S																					
294	Vonore	Tan sandy shale	Sevier	B	52	36	S																					
295	Vonore	Grey fossiliferous limestone with tan silty laminations	Sevier?																									
296	Vonore	Red poorly cemented fine grained sandstone	Sevier	B	47	32	S																					
297	Vonore		Quaternary																									Residuum
298	Vonore		Quaternary																									Alluvial
299	Vonore		Quaternary																									Residuum with widely scattered cobbles
300	Vonore		Quaternary																									Alluvial
301	Vonore		Quaternary																									Alluvial/ residuum with widely scattered cobbles
302	Vonore		Quaternary																									Alluvial
303	Vonore		Quaternary																									Alluvial
304	Vonore		Bays																									
305	Vonore	Brick red medium to thick bedded calcareous siltstone	Bays	B	0	0																						
306	Vonore	Red siltstone/sandstone	Bays	C	60	80	S																					
307	Vonore	Medium bedded siltstone	Bays	B	55	20	S																					
308	Vonore	Brick red medium bedded calcareous siltstone/very fine sandstone	Bays	B	50	30	S																					
309	Vonore	Brick red massive siltstone	Bays	B	41	34	S	C	26	85	N																	
310	Vonore	Coarse grained sandstone float	Quaternary																									
311	Vonore	Fine grained sandstone	Bays	B	45	20	S																					
312	Vonore	Grey calcareous sandstone	Bays/Sevier	B	70	30	S																					
313	Vonore	Brick red calcareous cross bedded sandstone	Bays?	B	52	27	S																					
314	Vonore	Gray to pink sandy limestone, sparry	Bays	B	65	20	S																					
315	Vonore	Brick red brown cross bedded fine grained calcareous sandstone	Bays	B	45	22	S																					
316	Vonore		Quaternary																									Residuum
317	Vonore	Chippy tan shale float	Quaternary																									
318	Vonore	Brick Red medium grained medium bedded cross bedded calcareous sandstone	Sevier	B	35	34	S																					
319	Vonore	Cross bedded medium thickness sandstone with ripple marks	Sevier	B	47	27	S																					
320	Vonore	Tan shale float	Sevier																									
321	Vonore	Poorly cemented (hematite) red sandstone float	Sevier?																									
322	Vonore	Tan shale	Sevier?																									
323	Vonore	Siltstone cobbles	Sevier?																									
324	Vonore	Tan calcareous shale float	Sevier?																									
325	Vonore	Siltstone with soft sediment deformation	Bacon Bend																									
326	Vonore	Red fine grained sandstone	Bays?	B	55	24	S																					
327	Vonore	Brick red siltstone	Bays	B	44	19	S	C	38	90																		
328	Vonore	Calcareous siltstone/ very fine sandstone	Bays	B	52	20	E	C	42	88	N																	

Station No.	Terrace level	Comments
290		Bedding may not be accurate
291		pink calcite some cross bedded looking layers, fossiliferous bryozoans are only ones identifiable.
292		
293		small sandstone lenses as well
294		
295		Brachiopod can't get good bedding, 100ft down road, fine grained poorly cemented sandstone
296		Ripple marks
297	920	Knox residuum, solid to powdery chert nodules over entire hill
298	820	some Knox residuum
299	825	
300	850	Sequoyah Birthplace, Hugh says mica may be indicative of Alluvial history, found clast of what was sandstone, crumbliness of 4
301	940	Picture 3.14,quartz pebbles in Bays Residuum, Hugh says may be reworked. Qtz cobbles are 1's and 2's, ring when struck, not much weathering
302	810-820	Lower-high terrace, 1's and 2's qtz. Pebbles, reddish soil, lots of cobbles across railroad tracks, some 3.5's to 4.5's her, to south at Tellico contact Tan shale residuum with 30 cobbles/square meter(moderate density of cobbles)
303	830	Contact between Alluvial gravely soil and residuum, picture 3.15, contact between gravel top/residuum bottom, Hugh suspects it might be a stream channel
304		Walked across lots of bays residuum
305		
306		
307		Typical cleavage but too random to get measurement, sporadic outcrop all along this ridge
308		intermittent cleavage
309		
310		Angular to sub rounded clasts of coarse grained sandstone with sub-rounded to rounded grains, hematite cemented? No fizz
311		
312		must be near Bays/Sevier contact
313		
314		
315		
316		Residual soil and sinkhole with rather recent collapse(2 years? based on trees) opening to deeper portion but not going down alone
317		
318		
319		
320		
321		
322		In Tree Fall
323		In tree fall
324		
325		In tree fall
326		
327		
328		Thick Bedding Discontinuous Cleavage

Station No.	Quadrangle	Rock type	Unit name	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Quaternary Unit Type
329	Vonore		Quaternary																									Alluvium
330	Vonore		Quaternary																									Alluvium
331	Vonore		Quaternary																									Alluvium?
332	Vonore		Quaternary																									Alluvium
333	Vonore		Quaternary																									Residuum with scattered cobbles
334	Vonore		Quaternary																									Alluvium
335	Vonore		Quaternary																									Residuum with scattered cobbles
336	Vonore		Quaternary																									Residuum with scattered cobbles
337	Vonore		Quaternary																									Residuum with scattered cobbles
338	Vonore		Quaternary																									Residuum with Scattered cobbles
339	Vonore	Medium dark grey sparry limestone	Knox	B	59	65	S																					
340	Vonore		Quaternary																									Residuum with Scattered cobbles
341	Vonore		Quaternary																									Residuum with scattered cobbles
342	Vonore		Quaternary																									Alluvium
343	Vonore	Weathered limestone	Knox																									
344	Vonore	Sugary dolostone	Knox	B	330	16	N	Fr	345	84	E																	
345	Vonore	Grey limestone, sparry to micritic with black and gray laminated chert beds 2m thick	Knox	B	74	76	S																					
346	Vonore	Sugary limestone with resistant dark laminations	Knox	B	60	87	S																					
347	Vonore	Gray sugary limestone with raised laminations	Knox	B	42	70	S																					
348	Vonore	Medium grained sandstone, subrounded to rounded quartz, silica cemented with tan weathered out portions	Knox	B	45	72	S	B	65	81	S																	
349	Vonore	Interbedded lt. gray sugary dolostone/limestone	Knox	B	70	15	N																					
350	Vonore	Sugary dolostone	Knox	B	56	18	N																					
351	Vonore	Dark gray sugary dolostone	Knox	B	10	21	E																					
352	Vonore	Dark gray sugary dolostone	Knox	B	30	20	E																					
353	Vonore	Dark gray sugary dolostone	Knox	B	75	12	S																					

Station No.	Terrace level	Comments
329	840 feet	Near station 27, 40 feet above water level, near sinkhole, cobbles of quartzite/sandstone up to 10 cm in diameter, 20 or so per square meter, well rounded, soil color slightly redder than 5 Y/R 3/4 moderate brown, hardness 1's and 2's
330	850 to 860 feet	Scattered cobbles, rounded quartzite, 26 cm and down, 1's and 2's, maybe alluvium upon digging found more cobbles under surface
331	860 feet	Cobbles of quartzite/sandstone, 14 cm and down, 15-30 per sq. meter, hardness 1's/2's in a 5 Y/R 3/4 moderate orange soil, on west side of road similar, 30-40 cobbles/ sq. meter visible in some locations, some angular limestone cobbles but only 3-4/sq meter
332	860 to 880 Feet	Cobbles in tree falls along power lines, well rounded sandstone cobbles, 3 to 4 cm in size, 20/ sq. meter, 1's and 2's, soil color 5 Y/R 5/6 light brown, some mica, in woods 12-15 cm cobbles sandstone, 1's and 2's hardness
333	880 feet	Rounded quartzite cobbles, 2-15 cm and down, 6-10/ sq. meter, hardness of 1's and 2's, soil color 5 Y/R 3/4 moderate reddish brown, moderate mica, some angular limestone float
334	920 to 960 feet	Rounded sandstone cobbles 6-10 cm in length starting about 910 or 920, 20's/sq meter, Hardness 1's and 2's, soil color 5 Y/R 3/4, To west on ridge, Alluvial deposits seem to ring crest , become more like residuum with scattered cobbles 5 ft from top
335	900 feet	Mica rich soil, 5 Y/R 3/4 moderate brown, few mixed cobbles of chert and sandstone, 1/sq meter, 2-5 cm across
336	840 feet	Soils map calls this Etowah, generally smaller pebbles 1-2 cm of sandstone(rounded) chert(rounded and limestone (sub-angular), lots of mica, soil is 5 Y/R 3/4 moderate brown, looks like colluvium from further upslope or residuum w/scattered cobbles
337	860 Feet	Rounded sandstone and Quartzite Cobbles, 10-15 cm, 5-10/sq meter, 1's and 2's, right next to change in slope, probably colluvial deposit, 5 Y/R 2/4
338	860 Feet	Mix of Chert and Mostly sandstone, 20's/ sq. meter, 1's some 2's, 5 Y/R 3/4, , most likely colluvial Alluvium given high slope and proximity to road
339		Hard to find good bedding plane
340	840 feet	Sandstone cobbles 2-4 cm in length, Angular limestone fragments, soil is 5 Y/R 3/4 moderate brown
341	840 Feet	Fort Loudon, Flat portion of peninsula is residuum with scattered cobbles of 2-4 cm diam. rounded conglomerate and quartzite with smaller angular limestone, area is maintained as a lawn so pebbles are hard to find and may give false impression, upper fort
342	820 feet	Cobbles of well rounded quartzite/sandstone in small berm along shore, cobbles from 4-6cm in diameter and down, 30-50/sq. meter, occasional subangular limestone fragment, lots of sand, fine grained, rounded quartz sand with about 20% clay and dark material
343		Too weathered to see good bedding, mottled dark and light gray, crystalline but too small to see individual grains
344		Barely Fizzes
345		Can't tell if overturned or not
346		small quarried region, 30 ft of outcrop, has slightly raised more resistant laminations. I assume mark bedding
347		Laminations perpendicular to bedding face and straight rill like weathering gouges on bedding surface
348		Weathered out portions Feldspar? Clay? In Knox?10 ft thick, Probably base of Chepultepec based on later observations with Bob, dolostone at same elevation to west 30ft away, light gray, 20 ft below dolostone, ridged laminations in dark gray limestone. Bedding taken in limestone.
349		
350		Bedding hard to tell
351		White/Cream/Ivory Chert nodules assume mark bedding
352		
353		

Station No.	Quadrangle	Rock type	Unit name	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Quaternary Unit Type
354	Vonore		Quaternary																									Residuum with Scattered cobbles
355	Vonore		Quaternary																									Residuum with Scattered cobbles
356	Vonore		Quaternary																									Residuum
357	Vonore		Quaternary																									Residuum with Scattered cobbles
358	Vonore	Tan, gray shale	Conasauga	B	65	34	S																					
359	Vonore		Quaternary																									Residuum with scattered cobbles
360	Vonore		Quaternary																									Residuum with scattered cobbles
361	Vonore	Tan/green mudstone	Conasauga	B	55	45	S																					
362	Vonore	Tan shale	Conasauga	B	40	75	N	B(ot)	41	76	N	FA	240	26	S	AP	59	31	N									
636	Vonore		Quaternary																									Alluvium
364	Vonore	Gray and tan calcareous shale float	Athens																									
365	Vonore	Medium bedded non-calcareous silty/fine sandy shale	Athens																									
366	Vonore	Gray very fine grained calcareous sandstone float	Athens																									
367	Vonore	Calcareous finely laminated medium thickness fine grained sandstone	Athens																									
368	Vonore	Tan weathered gray calcareous fine grained sandstone	Athens	B	80	15	S	B	290	20	S																	
369	Vonore	Calcareous shale/ micritic limestone, just because it's not thinly bedded	Athens	B	300	14	S																					
370	Vonore	Medium gray medium bedded medium grained sandstone interbedded with sparse shale lenses	Chapman Ridge	B	39	22	S																					
371	Vonore	Tan bioturbated(?) fine grained thinly bedded sandstone	Chapman Ridge	B	50	36	S																					
372	Vonore	Grey with tan weathering calcareous fine grained sandstone with some feldspar fragments	Chapman Ridge	B	65	27	S																					
373	Vonore	Grey calcareous fine grained sandstone	Chapman Ridge	B	72	32	S																					
374	Vonore	Grey thinly bedded calcareous fine grained sandstone	Chapman Ridge	B	72	35	S																					
375	Vonore	Calcareous thinly bedded gray silty shale	Athens	B	52	22	S																					
376	Vonore	Tan thinly bedded calcareous silty shale	Athens	B	33	30	S																					
377	Vonore	Silty calcareous shale	Athens	B	47	27	S																					
378	Vonore	Silty/fine sandy calcareous shale	Athens	B	280	84	S	B	58	47	S	Fr	37	47	NW													
379	Vonore		Quaternary																									Alluvium
380	Vonore		Quaternary																									Soil
381	Vonore		Quaternary																									Suspected Alluvium

Station No.	Terrace level	Comments
354	900 Feet	Rounded Quartzite, 2-5/sq.meter, 5-8cm in diameter, some mica flakes, 1's and 2's
355	920 Feet	Clasts of rounded sandstone 5-10cm across, soil 5 Y/R 5/6 light brown, 2's
356	840 Feet	Red Brown Residuum with scattered quartzite cobbles, Angular limestone pebbles also abound, near Athens Blockhouse so know soil has been reworked
357	900 Feet	Rounded Scattered quartzite/sandstone Cobbles, up to 10 cm, 5-6/sq meter, smaller angular limestone fragments, soil 5 Y/R 4/4 Moderate Brown
358		
359	900 feet	Scattered large cobbles
360		Rounded Quartzite cobbles, 1's and 2's hardness, 2-6 cm in length, 6-7/sq meter, no mica, no limestone, but lack of good exposure prohibits declaration as terrace, some limestone fragments towards road
361		
362		Picture 3.17-3.18, fold, picture 3.19, smaller scale fold on larger fold, 3.20-3.21, smaller scale fold below main fold, this site has been bulldozed
636		Have feeling I'm on terrace, Well rounded quartzite/sandstone cobbles, 30-50/sq meter, 10-15 cm in size on down, 1's and 2's, occasional 2.5's, breaks in hand but only the weathering rind, some residuum
364		
365		Ridge is capped by this stuff
366		
367		
368		strange cobble shaped weathering pattern in some locations looks superficially similar to Bacon Bend member of Sevier but not as concentrated, 2nd bedding is down slope consisting of silty/ sandy shale
369		
370		Picture 3.22, typical exposure of calcareous sandstone(gray) red weathering rind
371		
372		
373		
374		
375		
376		
377		
378		Complication, Hard to tell bedding, small fold but hard to visualize
379	900	Alluvium but I don't think it's very thick, Rounded quartzite/sandstone cobbles, 1's and 2's occasional 3, 40-50/sq meter, 8-10 cm across, hard to identify rock type, looks like red brown fleshy gypsum cemented medium grained sandstone
380	900	Soil is brown, Closest color on rock chart Moderate Brown 5 Y/R 3/4, does not stick together very well most soil in the area is closer to dark reddish brown 10 Y/R 3/4 but slightly less red like an 8 Y/R 3/4
381	900	Alluvium but I don't think it's very thick, Rounded quartzite/sandstone cobbles and chert, 1's and 2's occasional 3, 40-50/sq meter, 8-10 cm across, hard to identify rock type, looks like red brown fleshy gypsum cemented medium grained sandstone, soil color 8 Y/R 3/4

Station No.	Quadrangle	Rock type	Unit name	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Quaternary Unit Type
382	Vonore		Quaternary																									Residuum with scattered cobbles
383	Vonore		Quaternary																									Alluvium
384	Vonore	Dark red brown calcareous siltstone	Sevier	B	39	6	S	FA	60	26	N	B	280	16	N	B	62	58	N									
385	Vonore	Tan very fine grained silt/sandstone float	Bays?																									
386	Vonore	Light gray and tan silty shale	Grainger/ Bays?	B	65	15	N																					
387	Vonore	Thickly bedded limestone	Knox	B	55	12	S																					
388	Vonore	Tan and green thinly bedded shale	Conasauga	B	63	43	S																					
389	Vonore	Dark grey limestone with widely scattered veining in contact with shale	Knox/Athens	B	65	45	S																					Residuum
390	Vonore	Light to medium grey pitted limestone	Knox	B	80	33	S																					Residuum
391	Vonore		Quaternary																									Residuum with scattered cobbles
392	Vonore		Quaternary																									Alluvium
393	Vonore	Dark brown shale	Conasauga	B	56	6	S																					
394	Vonore		Quaternary																									Alluvium
395	Vonore		Quaternary																									Alluvium
396	Vonore		Quaternary																									Alluvium
397	Vonore		Quaternary																									Residuum with scattered cobbles
398	Vonore		Quaternary																									Residuum with scattered cobbles
399	Vonore		Quaternary																									Alluvium
400	Vonore	Tan shale float	Conasauga																									
401	Vonore	Brick red sandstone	Chota?	B	54	23	S																					
402	Vonore	Slightly sandy limestone	Chota?	B	47	17	S																					
403	Vonore	Grey calcarenite with some cross bedding	Chota?	B	57	38	S																					
404	Vonore		Quaternary																									Residuum?
405	Vonore	Red and yellow claystone	Chota?	B	57	29	S																					
406	Vonore	Thinly bedded slightly silty calcareous shale with some small qtz. grains.	Chapman Ridge	B	60	15	S																					
407	Vonore	Limestone conglomerate? Large frosted quartz grains 5-8 mm in diameter		B	50	19	S																					
408	Vonore	Thinly bedded slightly silty calcareous shale	Chapman Ridge	B	60	25	S																					
409	Vonore	Calcareous sandstone		B	60	24	S																					

Station No.	Terrace level	Comments
382	900	Rounded quartzite/fleshy colored sandstone pebbles, 1's and 2's, 3-4cm across, not 10's/ sq. meter, some chert clasts most in fleshy colored stuff
383	900	Rounded quartzite/fleshy colored sandstone pebbles, 1's and 2's, 3-4cm across, 40-50/ sq. meter, some angular chert clasts, surrounds toqua cemetery, 90% sandstone, 10% chert
384		Small scale fold shaped like aspirin caplet in outcrop
385		Thinly bedded clay rich with some spheroidal weathering patterns
386		
387		
388		
389		
390	860	Soil is 5 Y/R 3/4 in color, soil is ever so slightly sand, clumps when moist but falls apart as chunks, occasional rounded cobble, tan to red sandstone, 5-7 cm in length, Hardness 1's
391	820	Rounded tan sandstone cobbles, 10's/sq meter, 7-10 cm, soil is on tan side of red brown
392	840	Clear cut, Rounded course red gypsum color sandstone 10/sq meter, 5-7 cm long, 1's and 2's, 10 Y/R 3/4 brown soil, some white crystalline quartz cobbles, 1-2/ sq. meter, occasional angular limestone fragment
393		Not very friable
394	860	Rounded sandstone cobbles, 30-50/ sq. meter, 10cm long, 1's and 2's, lots of limestone, subrounded, but looks rather fresh, may be road bed material
395	880	Tree fall exposure, good layer of rounded quartzite/sandstone cobbles, 30-50/sq meter, 5-10cm long, majority is 1's and 2's but occasional 3.5 (sandstone) and even 4 (crumbled in hand) dark green rock, picture 3.23, tree roots with alluvium, thickness of deposit estimated as 3 ft., Deposits on side of hill are probably derivative of this one
396	900-920	Rounded sandstone cobbles, 30-50/sq meter, 5-10cm long, majority is 1's and 2's but occasional 3.5 (sandstone) and even 4's, soil color is 5 Y/R 3/4 Red Brown
397	860	Big cobbles, well rounded sandstone, 20 cm on down, all 1's and 2's
398	820	Near Havco plant, Rounded quartz cobbles, 10-20/sq meter, 5-10 cm long, 1's and 2's, Angular limestone,1-10/sq meter, hard to tell if this is alluvium or colluvial alluvium from 900ft level terrace, can't be very thick regardless due to along strike proximity to limestone across river
399	860	Above train tracks near transformer substation, Rounded cobbles of sandstone, 20-30/sq meter, 5-7cm long, Dark Red soil, 10 Y/R moderate brown, can't be very thick, cobbles not evenly distributed, moved during rain?, indicative of channel?
400		
401		Brick Red saprolite, sandy, color 5 Y/R reddish brown, stringers of shaly material where bedding is apparent
402		Thinly bedded calcareous shale with a little sand across street, Tellico
403		very fine grained sand in limestone, matrix fizzes, some place have cross bedding which tends to be more resistant to weathering and sticks out
404		Rounded light colored Chert cobbles, 20/sq meter, 5cm in length, occasional large cobble(20cm across), occasional limestone fragments, mainly 1's for hardness, 1mm weathering rind, light tan soil, probably residuum but from where?
405		
406		
407		Brown areas of rock are generally low in limestone content, contain small grains of frosted quartz and something else, hematite cement? Clasts or areas of calcarenite, fine grained calcareous cemented sandstone also present in discreet layers of what look like debris deposits, picture 4.1-4.3
408		Picture 4.4-4.5, nice bedding surface probably just above Tellico (Athens) -Chota contact
409		small(1mm) brachiopod fossils, tan to smoky clear quartz frosted grains, kind of hard to tell if bedding present

Station No.	Quadrangle	Rock type	Unit name	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Quaternary Unit Type
410	Vonore	Light olive gray medium thick bedded calcareous siltstone/very fine grained sandstone		B	68	34	S	C	65	62	S																	
411	Vonore	Brown-orange sparry limestone with plag fragments	Chota?	B	40	30	S																					
412	Vonore	Gray calcareous fine grained sandstone with some cross bedding	Sevier?	B?	57	12	S																					
413	Vonore	Tan shale interbedded with calcareous sandstone		B	47	20	S																					
414	Vonore	Red sandstone with calarenite clasts		B	62	26	S																					
415	Vonore	Medium to thinly bedded sandy calcareous shales	Chapman Ridge	B	65	44	S																					
416	Vonore	Tan to dark brown weathering silty, calcareous, shale	Athens?	B	55	42	S																					
417	Vonore	Limestone float																										
418	Vonore	Thinly bedded calcareous shale	Athens	B	35	24	S	B	84	24	S																	
419	Vonore	Light gray sugary dolomite	Copper Ridge	B	63	55	S																					
420	Vonore	Light tan thinly bedded calcareous shale		B	70	16	S																					
421	Vonore	Gray thin to medium bedded calcareous fine grained sandstone		B	73	15	S																					
422	Vonore	Medium bedded medium grained calcareous sandstone		B	49	25	S																					
423	Vonore	Calcareous sandstone		B	50	27	S																					
424	Vonore	Medium bedded calcareous sandstone		B	43	27	S																					
425	Vonore	Tan thinly bedded silty shale		B	47	10	S																					
426	Vonore	Gray thinly bedded sandy/silty calcareous shale		B	40	29	S																					
427	Vonore	Thin to medium bedded fine/medium grained calcareous sandstone		B	74	20	S																					
428	Vonore	Calcareous sandstone		B	64	32	S																					
429	Vonore	Red tinted, gray calcareous fine grained sandstone	Chota	B	67	19	S																					
430	Vonore	Gray thick bedded medium to fine grained calcareous sandstone		B	46	22	S																					
431	Vonore	Buff, weathered, limestone with abundant fossils, mostly bryozoans	Chota																									
432	Vonore	Thinly bedded tan/brown silty shale		B	67	8	S	B	35	22	S																	
433	Vonore	Shale and fossiliferous limestone		B	65	23	S																					
434	Vonore	Gray with red tint massive bedded , medium grained sandstone		B	65	23	S																					
435	Vonore	Tan/gray thinly bedded calcareous silty shale	Sevier	B	34	27	S																					
436	Vonore	Tan/brown thinly bedded calcareous silty shale	Sevier	B	35	25	S																					
437	Vonore	Fossiliferous limestone	Holston/ Chota																									
438	Vonore																											Residuum
439	Madisonville	Medium dark grey medium bedded sparry limestone with fine silt laminations		B	60	36	S	B	40	1	S																	
440	Vonore	light gray sparry limestone		B	57	23	S	Fr	74	70	N																	
441	Vonore	limestone																										Residuum with some chert
442	Vonore	Arkosic sandstone	Copper Ridge	B	57	16	N																					
443	Vonore		Quaternary																									Residuum with some chert
444	Vonore		Quaternary																									Suspected alluvium
445	Vonore		Quaternary																									Terrace Deposit
446	Vonore		Quaternary																									Terrace Deposit

Station No.	Terrace level	Comments
410		some cleavage in siltier places
411		
412		reddish tint in places
413		occasional quartz grains within the shale
414		
415		Transition between more shaly and more sandy units, medium bed thickness in sandy units, thinly bedded in the shales
416		similar to station 408 except bedding is not as good, Transitional area?
417		
418		occasional silty bed
419		
420		slightly silty in spots, yellow blue cross bedded calcareous sandstone
421		
422		finer grained sandstone float and shale mark flat portion of ridge, this sandstone is the reason for change to steeper slope
423		Calcareous thinly bedded silty shale in lower portion of saddle
424		
425		
426		
427		
428		walked over silty shale in saddle
429		Tan rounded grains of quartz, has resistant cross beds
430		some cross bedding but not prominently weathering as much as other outcrops, This station is near the top of almost complete exposure along north slope at hill, displays very prominent cross beds nearly 140-160 ft thick, pictures 4.6,4.7,4.8
431		Face is too weathered to get bedding, strike appears to be consistent with regional strike, Holston equivalent, some corals/bryozoans near hear, teaming with fossils
432		Just 100 ft up road calcareous shale
433		above topographically and stratigraphically what I thought was Chota
434		
435		
436		
437		bedding too hard to tell, crinoids/brachiopods/bryozoans
438		mix of angular limestone and fine grained well sorted quartz sandstone fragments, typical light red brown clayey soil but has somewhat more sand components, widely scattered rounded chert and sandstone cobble
439		messy weathered dolomite 10 ft down more massive looking mixed dark and light areas much less weathered pattern, further north down hill
440		
441		Angular cobbles with occasional exposed saprolite, white sandstone with 3 mm weathering rind, no other round cobbles,1 or 2 /sq. m.
442		Rather thin bed, 1/2 ft or less
443		Small area of occasional rounded 10 cm sandstone and white, occasionally slightly pink mostly angular limestone fragments
444		Same as 296, Scattered cobbles of white sandstone and chert and pink sandstone, 10's/sq m, 1's and 2's mostly with an occasional 4, well rounded to rounded, 8-10cm on down in size, in red brown soil with lots of weathered angular limestone fragments
445	860 ft	20-40/sq m, 15 -10 cm on down, well rounded, generally white sandstone with occasional chert cobbles
446	880 ft	same as 445 description,

Station No.	Quadrangle	Rock type	Unit name	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Quaternary Unit Type
447	Vonore		Quaternary																													Terrace Deposit
448	Vonore	Dark gray sugary dolostone	Chepultepec	B	35	15	S																									
449	Vonore		Quaternary																													Suspected Alluvium
450	Vonore		Quaternary																													Residuum
451	Vonore	Dolomite	Copper Ridge	B	68	34	SE																									
452	Vonore	Sandstone with ripple marks	Chepultepec	B	63	88	SE																									
453																																Terrace
454	Vonore	White oolitic limestone	Chepultepec																													
455	Vonore	limestone		B	52	27	E																									
456	Vonore	limestone	Lenoir	B	78	10	S																									
457	Vonore	Subrounded, medium grained, chert cemented sandstone	Mascot	B	76	25	S																									
458			Quaternary																													Terrace
459		Limestone																														Residuum
460		Purplish gray medium grained quartz sandstone																														
461	Vonore		Quaternary																													Residuum
462	Vonore		Quaternary																													Scattered cobbles in residuum
463	Vonore	White sandstone float																														
464	Vonore	Fine grained silica cemented sandstone float																														
465	Vonore	Tan thinly bedded shale	Conasauga?	B	82	80	S																									
466	Vonore	Tan folded shale	Conasauga?	B	53	32	S																									
467	Vonore	Light gray, tan and gray mottled limestone		B	63	63																										
468	Vonore	Quaternary																														
469	Vonore	Dark gray sparry limestone float	Mascot?																													
470	Vonore	Silica cemented sandstone float	Copper Ridge/ Chepultepec																													
471	Vonore	Silica cemented sandstone float	Copper Ridge/ Chepultepec																													
472	Vonore	Dark grey limestone with some resistant laminar layers	Chepultepec	B	74	55	S																									
473	Vonore	Sandstone	Copper Ridge/ Chepultepec	B(ot)	278	65	N																									
474	Vonore		Quaternary																													
475	Vonore	Massively bedded limestone	Quaternary																													
476	Vonore																															
477	no station																															
478																																
479	Vonore	Fossiliferous light gray limestone	Lenoir	B	56	49	S																									
480	Vonore	Tan silty shale with dark pebbles of dark material, Ironstone?	Lenoir/ Blockhouse	B	57	23	S																									
481	Vonore	Dark gray massive dolostone and limestone with fossil hash	Mascot?	B	42	20	S																									
482	Vonore	Thinly bedded black calcareous shale slightly sandy in some parts	Quaternary																													Alluvial?

Station No.	Terrace level	Comments
447		Smaller rounded cobbles of quartz sandstone, 4-6 cm, 20-40/sq. m, 1-2 hardness, might have something to do with sink hole but don't know what.
448		
449		picture 10 is of mud cracks, 10-20/sq m, 1-2's hardness, small 5-8 cm rounded cobbles , mostly white clean sandstone, also some black and pink chert and microcrystalline quartz
450		Some areas of scattered cobbles of 1-2 hardness, 5-8cm , well rounded clean sandstone that may make it into 10/sq. m but mostly 1-2/ sq. m, don't seem to follow a pattern
451		
452		
453		
454		
455		
456		
457		Bob says wow
458		Well rounded cobbles of white quartzite, 5 cm on down, 30 to 40/sq cm, 1's and 2's , soil color 10 y/r 5/5 Reddish Moderate Brown, some angular to subrounded limestone
459		Float is angular
460		no good bedding
461		Round Quartz pebbles in runnel along road, 30 to 40/sq m,1's mostly, 6cm on down , poorly sorted as usual, higher up on hill only angular limestone fragments
462		walked across residuum as moved north up road , well rounded quartzite cobbles, 4-5cm across, 3-4/ sq m in pods, some angular poorly cemented, sandstone float also between 462 and 438
463		
464		
465		
466		
467		
468		Rounded white sandstone cobbles, 5-8cm, 20's/sq meter, Maynardville limestone fragments as well as chert, 1's and 2's
469		
470		
471		
472		
473		part of a small fold sands tone outcrop is only about a foot thick and mostly covered so hard to tell orientation of fold
474		well rounded quartz sandstone, cobbles 1's and 2's, 8cm and smaller, poorly sorted, 20 to 40/sq meter, soil color 10y/r 6/6 dark yellowish orange
475		All in tree fall, surface exposure sucks, well rounded sandstone cobbles, 2's and 3's, can break with hands, 5-8 cms across, 1-2 mm weathering rind 5 y/r 3/4 Dark moderate brown
476		
477		
478		
479		Brachiopod fossil has, some other gastropods also
480		In excavated portion, can see contact between Tellico and Blockhouse, Changes from limestone to Black/Tan/green/red shale for 40 ft. to well sorted well rounded ironstone for 2-3 ft. and then tan/red shale with very fine grained sandstone in core of fold, pictures 4.13, Lenoir/shale contact hammer on top of Lenoir, 4.14, shale above limestone, 4.15 broad small scale fold in Tellico?, 4.16 Fold from farther away with fine grained sandstone in core clipboard on sandstone
481		contact?
482	970-980	Might be alluvial clean white sandstone cobbles as well as red/pink sandstone/quartzite, all well rounded, 10cm and down, 20/sq meter,1's and 2's with 1 mm weathering rind, soil color is 5 Y/R 3/4 moderate brown, slope makes me wonder if this isn't transported, no mica

Station No.	Quadrangle	Rock type	Unit name	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Quaternary Unit Type
483	Tallassee	lt. grey limestone float SOLID		B	51	44	S																									
484	Tallassee	Calcareous shale: black, dk. gray, tan, thinly bedded																														
485	Tallassee	Dark gray calcareous shale thinly bedded		B	54	55	S																									
486	Tallassee	Calcareous siltstone float		B	52	86	S																									
487	Tallassee	Black oolitic stuff Bob calls ironstone - I think this is our marker bed at base of Athens/Lenoir contact		B	70	86	S																									
488	Tallassee	Black calcareous shale, more calcareous portions have poorer parting																														
489	Tallassee	Same as above	Blockhouse?	B	356	34	NE																									
490	Tallassee	Medium bedded calcareous shale, nearly limestone in appearance		B	74	20	S																									
491	Tallassee	Dark gray, organic smelling massive sparry limestone		B	65	72	S	B	330	4	N																					
492	Tallassee	Light grey massive sparry limestone float almost completely crystalline		B	50	70	S																									
493	Tallassee	Thinly bedded tan brown shale																														
494	Tallassee	Light gray limestone	Athens?/ Lenoir	B	52	39	S	B	40	29	S																					
495	Tallassee	Gray limestone	Lenoir	B	38	15	S																									
496	Tallassee	Shale - tan and thinly bedded		B	55	35	S																									
497	Tallassee	Tan and gray calcareous shale - thinly bedded		B	42	36	S																									
498	Tallassee			B	47	64	S																									
499	Talassee	Tan shale float																														Alluvium
500	Vonore	Medium bedded grey/slightly pink slightly sparry limestone	Mascot/ Lenoir	B	25	24	S																									
501	Vonore	Limestone with banded chert nodules	Mascot?																													
502	Vonore	Rounded white silica cemented sandstone cobble 20 cm across	Mascot/ Longview																													
503	Vonore	Gray sparry,medium thickness bedding limestone	Mascot?	B	76	17	S																									
504	Vonore	Poorly cemented tan sandstone float, Red brown dark oolitic limestone in place,	Blockhouse?/ Lenoir?	B	46	22	S																									
505	Vonore	Light gray, medium bedded limestone	Lenoir	B	42	23	S																									
506	Vonore	Tan silty thinly bedded shale with some cleavage	Athens	B(ot)	320	41	E	C	314	49	E	B	20	30	E																	
507	Vonore	Dark grey, thickly bedded featureless limestone with some resistant tan layers	Mascot	B	40	29	S																									
508	Tallassee	Tan calcareous shale	Athens	B(ot)	32	79	N																									
509	Tallassee	Non calcareous shale with some silt	Athens	B(ot)	20	81	N																									
510	Vonore	Tan/grey thinly bedded calcareous shale	Blockhouse/ Athens	B(ot)	30	87	NW																									
511	Vonore	Massive grey crystalline dolomite float	Mascot?																													
512	Vonore	Chert float with maybe some sand	Longview/ Mascot																													
513	Vonore	Silica cemented sandstone and light grey limestone float	Longview/ Mascot																													
514	Vonore	Limestone	Mascot? Lenoir?	B(ot)	72	26	N																									
515	Vonore	Grey limestone with silica cemented sandstone float	Mascot	B	332	11	W																									
516	Vonore	Shale, Silica cemented sandstone float	Toqua?	B	35	19	N																									
517	Vonore	Dolomite	Mascot/ Lenoir	B	42	38	S																									
518	Vonore	Tan/grey thinly bedded calcareous shale and gray limestone	Blockhouse/ Lenoir	B	39	47	N	B	36	29	N																					
519	Vonore	Medium bedded light grey limestone	Mascot	B	15	8	W																									

Station No.	Terrace level	Comments
483		
484		
485		
486		Picture 5.1-5.3 showing ?????? Of Tellico from Tellico/Blockhouse Ridge. Ridges in distance are sandier upper Tellico (Chapman Ridge)
487		
488		Sample definitely has dark red iron oxide look
489		small scale fold or (?larger?) trend might not be enough exposure to tell
490		appears to be small scale fold. Same rock here is in correct orientation
491		medium bedded calcareous shale, nearly limestone in appearance but can break apart with hands in to nice planes. Upon further inspection appears to be crapped up fold. Bedding to east is nearly horizontal.
492		fossil hash in places, crinoids, nice brachiopods. Picture 5-4-99 brachiopods, Picture 5-6 Big ass spider
493		
494		might be nose of fold, what looks to be Tellico (Athens) shale, 2nd bedding measurement Lenoir Limestone, some fossils, brecciation, bedding not apparent
495		
496		bedding eyeballed because on other side of fence with cows.
497		
498		
499	880	Tan/flesh colored sandstone/quartzite, pebbles of well rounded, moderately well sorted, 2-4 cm in length, 50-60/sq meter, 1's and 2's, some have polished look, occasional dark chert
500		In Ninemile creek, at Thompson bridge, nose of fold
501		Float of frosted qtz medium grained sandstone
502		2mm thick weathering rind, manganese?
503		
504		Lenoir is probably up hill due to presence of ironstone float, limestone is in place probably Mascot
505		
506		Picture 5.6 ,Chicken audience
507		
508		
509		Alternating calcareous and non calcareous beds
510		so thin in map projection due to verticality of the beds
511		
512		
513		Walking across reddish brown soil, limestone weathering?
514		No marker beds present so hard to tell stratigraphic location
515		I think it's mascot due to proximity of silica cemented sandstone float
516		
517		Near Mascot/Lenoir contact, can't see contact between Lenoir and Mascot and Lenoir and Blockhouse but soil transition from red to mottled red/tan and tan in Tellico along with float
518		Picture 5.7, Non excavated Tellico (Athens)-Lenoir contact relationship, Hammer is near center of picture
519		Picture 5.8-5.11, layering in Mascot, looks like crossbedding

Station No.	Quadrangle	Rock type	Unit name	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Quaternary Unit Type
520	Vonore	Massive limestone with fossil hash, brachiopods, shell layers 3-5cm thick	Mascot/ Longview	B	30	24	N																									
521	Vonore	Medium bedded gray limestone	Mascot	B	52	35	S	B	54	34	S	B	40	82	S																	
522	Vonore	Thinly bedded shale	Athens	B(ot)	50	89	NW																									
523	Vonore	Thinly bedded gray calcareous shale	Athens	B	84	22	S																									
524	Vonore	Tan to buff, fine grained quartz calcite cemented sandstone	Toqua?	B	65	35	S																									
525	Vonore	Tan interbedded sandstone and silty/fine sandy shale	Athens	B	55	88	S																									
526	Vonore	Tan shale	Athens	B	46	41	S																									Residuum with scattered cobbles
527	Vonore	Gray fine grained calcite cemented sandstone		B	40	20	S																									
528	Vonore	Gray fine grained subangular limestone		B	355	5	W																									
529	Vonore	Light gray crystalline limestone	Lenoir?	B	290	11	S																									
530	Vonore	Gray/pink large grained crystalline limestone	Lenoir?	B	330	32	S																									
531	Vonore	Light gray aphanitic sparry limestone		B	40	27	S	B	60	17	S																					
532	Vonore	Chert cemented sandstone	Mascot/ Longview	B	75	22	S																									
533	Vonore	Gray dolostone/ limestone with sparse widely spaced interclasts		B	356	11	W																									
534	Vonore	Gray limestone	Lenoir	B	30	31	N																									
535	Vonore	Tan shale	Athens	B	57	41	S																									
536	Vonore	Tan and gray thinly bedded shale	Athens	B	70	67	S																									
537	Vonore	Calcareous sandstone	Athens	B	15	17	N																									
538	Vonore	Thin calcareous sandstone	Blockhouse/ Lenoir	B	42	11	S																									
539	Vonore	Fossiliferous limestone with dolostone lenses	Maynardville	B	56	46	S																									
540	Vonore	Light to medium gray fine grained dolomite with layered chert nodules		B	48	54	S																									
541	Vonore	Dark gray oolitic chert in sugary dolomite	Copper Ridge	B	60	40	S																									
542	Vonore	Sandstone	Copper Ridge/ Chepultepec?	B	58	65	S	B	55	86	E																					
543	Vonore	Dolomite, Stromatolitic?	Copper Ridge	B	65	76	S																									
544	Vonore	Dolomite molds in cherty layer below dolostone/limestone layer	Kingsport?	B	58	81	E																									
545	Vonore	Sandstone bounded by limestone	Copper Ridge/ Chepultepec	B	60	65	E																									
546	Vonore																															Stream Terrace deposit
547	Vonore	Medium to dark gray fine grained dolomite		B	68	38	S																									
548	Vonore	Massive bedded gray limestone with brown dolomite ribbons	Kingsport	B	66	45																										
549	Vonore	oolitic layer																														
550	Vonore	Dark gray sugary dolomite	Copper Ridge	B	57	76	E																									
551	Vonore	Gray oolitic limestone		B	54	85	S																									
552	Vonore	Dolomite with layer of chert pods	Copper Ridge	B	72	86	S																									
553	Vonore	Interbedded limestone/dolomite with some chert and gastropods	Kingsport	B	54	72	S																									
554	Vonore	Conglomeratic layer, fossils/ stromatolites, well rounded chert grains		B	55	62	S																									
555	Vonore	White silica cemented sandstone	Chepultepec	B	68	54	S																									
556	Vonore	Medium gray dolomite		B	69	16	S																									
557	Vonore	Dolomite with dolomite filled veins		B	66	32	S	B	52	17	S																					
558	Vonore	Pink/ light gray fine grained dolomite	Mascot/ Kingsport	B	69	34	S																									
559	Vonore	Gastropod limestone	Lenoir																													
560	Vonore	Thin beds of shale and sandstone	Lenoir?	B	47	26	E																									
561	Vonore	Pink to gray microcrystalline dolostone with fine laminated weathered surface		B	70	24	S																									

Station No.	Terrace level	Comments
520		
521		Mascot limestone, Silica cemented sandstone, Tellico (Athens) Blockhouse contacts
522		shale has taken up all deformation
523		
524		took sample maybe some feldspar
525		
526	840 feet	Tan rounded sandstone cobbles, ~10 cm, 10-20/sq m, hardness 1's and 2's, no weathering rims, tan soil
527		
528		
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531		
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536		
537		Stream flow keeps changing direction through restricted area of channel
538		
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541		
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545		
546	820 ft	Quartz/sandstone cobbles, up to 15 cm, 20/sq m,1's and 2's, with Copper Ridge and Chepultepec float
547		
548		
549		
550		
551		took sample
552		Pete found gastropod rich limestone directly below on shore
553		
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Station No.	Quadrangle	Rock type	Unit name	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Quaternary Unit Type
562	Vonore	Pink microcrystalline dolomite	Kingsport	B	35	21	S																									
563	Vonore	Dark gray microcrystalline medium to thick bedded limestone	Chepultepec	B	45	30	S																									
564	Vonore	Gray limestone		B	50	35	S																									
565	Vonore	Sandy unit with calcite blobs/veins and maybe calcite cement		B	45	23	S																									
566	Vonore	Light gray med to fine grained calcite cemented sandstone		B	50	23	S																									
567	Vonore	Finely laminated massively bedded pink tinted dolostone	Kingsport	B	80	24	S																									
568	Vonore																															Terrace
569	Vonore	Light gray medium thickness dolostone	Mascot?	B	52	33	S																									
570	Vonore	Black and white banded chert nodules in sandy gray limestone		B	52	27	S																									
571	Vonore	Dark gray dolomitic sandstone																														
572	Vonore	Dark gray micritic limestone dark gray brown intraclasts		B	54	22	S																									
573	Vonore	Dark to medium gray micritic limestone with occasional spar of calcite		B	62	27	S																									
574	Vonore	Tan/gray medium to fine grained calcareous sandstone	Mosheim?	B	50	27	S																									
575	Vonore	Sandstone with interbedded siltstone beds up to 2 inches thick		B	60	25	S																									
576	Vonore	Tan thinly bedded silty shale with occasional thin sandstone layer	Athens	B	50	45	S																									
577	Vonore	Brown/ gray argillaceous limestone	Lenoir?	B	56	24	S																									
578	Vonore	Calcite cemented sandstone	Toqua																													
579	Vonore	Sandy shale float and soil	Toqua?																													
580	Vonore	Pale green, tan and brown thinly bedded shale	Blockhouse?	B	49	59	S																									
581	Vonore	Thinly bedded green/gray calcareous shale	Athens	B(ot)	55	86	N																									
582	Vonore	Sandy area	Toqua?																													
583	Vonore	Tan orange shale	Athens	B(ot)	51	89	N																									
584	Vonore	Greeny-gray calcareous silty shale	Athens (Blockhouse)	B	52	65	S																									
585	Vonore	Tan thinly bedded shale	Athens	B	52	39	S																									
586	Vonore	Fine grained tan and orange silty sandstone with interbedded silty shale	Toqua	B	55	33	S																									
587	Vonore	Thin to medium bedded silty sand		B	51	34	S	Fr	341	75	W	Fr	296	79	E																	
588	Vonore	Medium grained gray calcite cemented sandstone with some red looking grains	Toqua?	B	39	38	S																									
589	Vonore	Dark gray micritic limestone with crystalline calcite grains in places	Lenoir	B	49	25	S																									
590	Vonore		Mascot/ Lenoir																													
591	Vonore	Limestone with some resilient banding of more silty layers		B	56	21	S																									
592	Vonore	Poorly cemented sandstone float with some small outcrop	Mascot/ Longview	B	40	20	S																									
593	Vonore	More fine grained sandstone	Mascot/ Longview	B	241	27	N																									
594	Vonore	Medium gray dolostone with chert nodules		B	51	12	S																									
595	Vonore	Dark gray dolostone with quartz grains		B	62	27	S																									
596	Vonore	Light gray dolostone		B	45	16	S																									
597	Vonore	Sandstone float																														
598	Vonore	Sandstone float																														

Station No.	Terrace level	Comments
562		
563		
564		Grainier
565		
566		
567		
568	840 ft	Probable terrace deposit with predominantly quartz pebbles and the weird pink sandstone. Some areas have very weathered siltstone but since they are right on the water, hard to tell if it indicates anything. Subangular to well rounded clasts about 6 cm in length poorly to moderate sorting, not many big clasts.
569		highly weathered cherts 80 ft to the north
570		
571		
572		
573		Outcrop looks like a jumble of colluvium even though it isn't, it is in place weathering to "psuedocolluvium" look
574		
575		Multiple feet of sandstone beds, sandstone is well rounded fine grained with siltstone in between, hard to tell cement but in some places poorly cemented, changes to predominantly siltstone in 100 feet
576		
577		ruble pile look , limestone breccia at top of ridge
578		
579		weathered orange/light brown quartz sandstone sample mostly residuum at this location
580		
581		bedding is north trending shore of parking lot is near vertical to slightly overturned
582		No good outcrop
583		Definitely in lower Tellico shale (Athens) all the shale is nearly vertical which may explain the change in thickness from across the river
584		
585		
586		
587		
588		spheroidally weathered where in contact with water, rocks here are more resistant than at 587, picture 1-3 Toqua calcite cemented sandstone in foreground with interbedded red-tan silty sandstone and shale at point, ridges are upper Tellico sandstone (Chapman Ridge).
589		took sample, picture 4 contact, backpack is on it, pictures 5-6 typical exposure
590		
591		
592		
593		highly fractured
594		
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Station No.	Quadrangle	Rock type	Unit name	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Quaternary Unit Type
599	Vonore	Light gray dolomite		B	72	24	S																									
600	Vonore	Sugary light gray dolomite		B	280	18	N																									
601	Vonore	Medium gray micritic limestone		B	55	19	S																									
602	Vonore	Dark gray sugary limestones		B	40	21	S																									
603	Vonore	Calcite cemented sandstone	Toqua?	B	49	26	S																									
604																																
605	Vonore	Organic medium gray sugary dolostone	Copper Ridge	B	61	47	N																									
606	Vonore	Sugary light gray dolomite	Copper Ridge?																													
607	Vonore	Dolomite	Copper Ridge?	B	50	53	S																									
608	Vonore	Tan to gray siltstone/carbonate shale	Conasauga?	B	70	73	S	B(ot)	62	68	N																					
609	Vonore	Dolomite with strong organic odor		B	45	46	S																									
610	Vonore	Chert bedded dolomite with organic odor	Copper Ridge?	B(ot)	67	86	N																									
611	Vonore	Dark gray micritic limestone		B	60	82	S																									
612	Vonore	Very fine grained white limestone	Chepultepec	B	65	78	S																									
613	Vonore	Light gray sparry dolostone with more resistant very thin silty layers		B	47	30	S																									
614	Vonore	Thin medium grained moderate to well sorted tan and red sandstone near dolomite and limestone	Chepultepec?	B	55	77	S	B	64	71	S																					
615	Vonore	Finely laminated to thickly bedded Micritic dark gray limestone	Chepultepec?	B	77	25	N																									
616	Vonore	Dark gray micritic thinly laminated limestone		B	42	45	N																									
617	Vonore	Dark gray micritic thinly laminated limestone with occasional chert nodules		B	54	36	N																									
618	Vonore	Sparry dolomite with large crystals		B	42	36	S																									
619	Vonore	Light gray dolomite with thin chert nodules	Chepultepec?	B	65	52	S																									
620	Vonore	Medium gray dolomite		B	49	44	S																									
621	Vonore	Brachiopod layer in micritic limestone		B	72	38	S																									
622	Vonore	Calcite cemented sandstone with slightly green tint		B	73	32	S																									
623	Vonore		Chepultepec																													Terrace
624	Vonore	Gray sparry limestone	Kingsport?	B	64	35	S																									
625	Vonore	Dark gray micritic limestone with chert nodules		B	65	30	S																									
626	Vonore	Coarse grained calcareous cemented arkosic sandstone	Sevier?	B	55	25	S																									
627	Vonore	Tan/green thinly bedded slightly calcareous silty shale	Sevier	B	50	39	S																									
628	Vonore	Interbedded calcareous fine grained sandstone, siltstone, and shale	Sevier	B	55	44	S																									
629	Vonore	Calcareous fine grained gray to weathered red brown massive sandstone	Sevier	B	51	31	S																									
630	Vonore	Tan-green silty shale	Sevier	B	46	39	S																									
631	Vonore	Red cross bedded medium to thick bedded medium grained sandstone	Chota?	B	60	37	S																									
632	Vonore	Grey-green thinly bedded calcareous siltstone	Chapman Ridge	B	49	31	E																									
633	Vonore	Gray/green calcareous siltstone and silty shale	Chapman Ridge	B	52	46	S																									
634	Vonore	Fine to medium grained calcite cemented sandstone	Chapman Ridge	B	80	43	S																									

Station No.	Terrace level	Comments
599		
600		large amplitude broad fold or monocline
601		
602		Lenoir is probably in valley to south
603		
604		
605		
606		too weathered to get bedding
607		
608		Same weathered outcrop, looks like Conasauga, crossed fault to north? Tan orange soil, stick to boots as well as more red soil associated with carbonate bedding. 100ft south along shore, green thinly bedded shale, Picture 18 facing along strike, overturned carbonate shale with mottling, transition from deeper water fine deposit in deepwater carbonate, lighter color is silty
609		occasionally very fine thin sandstone
610		apparent burrows on surface
611		Near vertical bedding all along this steep slope cliff, hope to see sandstone soon
612		Black oolitic limestone float, sandstone not quite where I expected it, does not outcrop well, little outcrop, only residuum and float of clean white sandstone, what outcrop exists is highly fractured and tilted so accurate measurement of dip is impossible
613		was very steep, now more normal. Weird, dip sandstone, have to take up slack/deformation
614		big chert nodules, weathered dolomite crystals, more continuous chert bedding
615		Bedding here is reversed of what it should be, is this a reaction to the folded Lenoir above? Actually outcrops like Lenoir and mascot contact but I don't think it is because of the sparriness of this limestone in some places
616		
617		Still Confused
618		bedding hard to tell but appears to have changed back to normal, no rock in between this and point with north dip
619		
620		
621		pictures 19-20, tip of pencil for scale
622		
623	820	cobble layers in slump, pictures 21-23 from south to north, picture 24 is at southern end, overlies Chepultepec, hill slope is 18 degrees most apparent folding is in photo 23 in the concave face below pipe, long axis of most cobbles seem to be into face
624		no real evidence for Kingsport, just gut feeling
625		
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629		
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631		I think it makes up these two ridges
632		
633		
634		Bedding 2-4 feet thick with thinner beds interfingered

Station No.	Quadrangle	Rock type	Unit name	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Quaternary Unit Type
635	Vonore	Thinly bedded calcareous fine grained sand	Chapman Ridge	B	41	30	S																					
636	Vonore	Thinly bedded tan/green silty shale	Chapman Ridge	B	55	24	S																					
637	Vonore	Thinly bedded tan/green silty shale	Athens	FA	30	37	E																					
638	Vonore	Thinly bedded tan/green silty shale	Athens	B	2	22	E	B	70	32	S																	
639	Vonore	Thinly bedded tan/green silty shale	Athens	B	60	43	S																					
640	Vonore	Thinly bedded tan/green silty shale	Athens	B	62	65	S	FP	85	60	S																	
641	Vonore	Tan silty shale	Athens	B	55	36	S																					
642	Vonore	Calcareous thinly bedded siltstone	Chapman Ridge	B	50	45	S																					
643	Vonore	Calcareous siltstone	Chapman Ridge	B	39	43	S																					
644	Vonore		Quaternary																									
645	Vonore	Highly weathered calcareous siltstone	Athens	B	25	65	W																					
646	Vonore	Thin to medium bedded calcareous siltstone		B	280	14	S																					
647	Vonore	Tan/green to gray thinly bedded calcareous shale	Athens	B	311	15	W	Fr	52	84	S																	
648	Vonore	Calcareous siltstone	Athens	B	330	7	W																					
649	Vonore	Tan/orange shale	Athens	B	349	12	W	B	80	25	S	B	85	55	N	FA	250	5	S									
650	Vonore	Tan/orange shale	Athens	B	80	25	S																					
651	Vonore	Tan shale	Athens	B	72	9	S																					
652	Vonore	Thin to medium bedded calcareous siltstone	Athens	B	65	35	S																					
653	Vonore			B	70	37	S																					
654	Vonore		Quaternary																									Terrace deposit
655	Vonore		Quaternary																									Residuum with scattered cobbles
656	Vonore	Calcareous siltstone with coarse sandy stringers		B	330	15	W																					
657	Vonore	Fine-medium grained calcareous ss. With coarse grained stringers																										
658	Vonore	Cross bedded calcareous sandstone	Chota?	B	30	24	S																					
659	Rafter	Red brown weathered to gray VFG carbonate ss. With siltier layers poorly cleaved	Bays	B	40	12	S	C	60	68	W																	
660	Rafter	Calcareous fine grained ss. Variable bed thickness, worm burrows?	Bays	B	70	15	S																					
661	Rafter	Slightly silty tan thinly bedded slightly folded shale		B	60	47	S																					
662	Rafter	Brown-red thinly bedded siltstone/VFG ss. - fractures - thinly bedded some shaly bits	looks like Bays - geol map says Rome	B	84	20	S	Fr	349	65	E	Fr	301	73	N													
663	Rafter	Cleaved calcareous siltstone	Bays	B	359	35	E	C	25	85	S																	
664	Vonore	Grey calcareous fine grained sandstone	could be Bays or Sevier	B	50	21	S																					
665	Vonore	Chippy tan shale float	Sevier																									
666	Vonore	Grey calcareous medium bedded sandstone		B	10	56	N																					
667	Vonore	Crinoid and brachiopod fossil hash in calcareous fine-grained sandstone	Sevier	B	85	21																						
668	Vonore	Red brown fine grained ss. float above tan and red interbedded shale & siltstone.	upper Sevier? possibly Bays?	B	313	26	S																					
669	Vonore	VFG thinly bedded ss.	Sevier?	B	76	14	S																					
670	Rafter	Red brown VFG ss. Underlain by more shaly thinly bedded siltstone/silty shale		B	340	6	W	FP	65	65	W																	
671	Rafter	Interbedded sh. & ss.: thin layers of shale, tan & thin slightly silty red V2F-grained, more thickly bedded ss.																										
672	Rafter		Quaternary																									Terrace deposit

Station No.	Terrace level	Comments
635		
636		near slump block, a little folding along strike, changes strike from n40e to n63e, no change in dip, folds have wavelength of 1.5 ft
637		area of what look to be highly folded shale but weathering by lake make me unsure, deposit in bank is poorly exposed and only shows broad along strike folding, moving from northwest to southeast, picture 1-2 are same, pictures 3-4 are shot parallel to strike, picture 6 hammer handle is oriented down hinge
638		Fold Axial plane too hard to tell, wavelength 27 ft
639		Consistent until another slump
640		
641		
642		
643		
644		Scattered cobbles in residuum, well rounded cobbles in Tellico residual clay, vein quartz, graywacke up to 6 inches in size, mostly 1-2 inch, probably high terrace
645		unsure of strike could be a fracture surface
646		
647		
648		
649		picture 7 along fold axis
650		
651		
652		
653		shore along toqua beach is all red soil, terrace gravel and hard packed clay residuum from the Tellico (Athens) shale
654	900 ft	20's of cobbles/sq meter. Sandstone and vein quartz, rounded to subrounded cobbles. Soil color 5YR 3/4 -moderate brown, pretty sandy clay soil.
655		5's of cobbles/sq. meter. May be terrace, but not enough here to justify yellow
656		
657		stringer layers 1mm - 2mm thick - discontinuous
658		medium scale fold + topography moves contact?
659		bedding thickness ranges from thick (5 ft) to medium(1 ft)
660		
661		OT? faulted? folded? bedding
662		fracture set occasionally filled with carbonate
663		
664		Vonore Quad near Martin's cemetery. Could be Bays or Sevier - weathering orange tan, so I'd probably call it Sevier.
665		
666		might be out of place but can't tell.
667		hard to tell if in place
668		I'm thinking upper Sevier, but red/brown stuff looks a lot like Bays
669		
670		occasional faulting looks like small normal faults - offset 8 inches
671		picture 4 (or maybe 9) -10
672	930 ft	quartz cobbles 6 in or less across, in chippy tan shale. Cobbles moderately well rounded, 10's to 20's per/ sq. meter. 1's and 2's (hardness). Soil color is 5YR 5/6 moderate brown.

Station No.	Quadrangle	Rock type	Unit name	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Quaternary Unit Type
673	Rafter	Grey ,coarse-grained calcareous arkosic sandstone																										
674	Rafter	Grey, weathering to red brown thickly bedded calcareous VFG ss.		B	69	10	N																					
674a	Rafter	Tan shale slightly silty		B	44	32	N																					
675	Mt Vernon	Tan/grey calcareous siltstone.		B	55	24	N																					
676	Mt Vernon	Tan/orange silty calcareous shale		B	76	15	N																					
677	Mt Vernon	Calcareous, medium-bedded fossiliferous quartz ss. & maybe colored chert-bearing ss.		B	76	20	N																					
678	Mt Vernon	Tan, thinly bedded calcareous shale		B	60	40	S	B	281	25	S																	
679	Mt Vernon	Red brown VFG ss. Thin to medium bed thickness		B	60	20	S																					
680	Mt Vernon	Red brown calcareous siltstone/ VFG ss.	Bays	B	346	17	E																					
681	Mt Vernon	Tan orange sandy shale float	Sevier? -probably Bays	B	40	5	S																					
682	Mt Vernon	Interbedded red brown medium bedded fine grained sandstone and tan/gray shale	Bays	B	43	15	S																					
683	Mt Vernon	Calcareous sandstone		B	55	44	S																					
684	Mt Vernon	Tan orange thinly bedded silty shale	probably still Bays	B	25	21	E																					
685	Mt Vernon	Tan and grey calcareous thinly bedded siltstone	Bacon Bend?	B	51	19	S																					
686	Mt Vernon	Calcareous sandy siltstone																										
687	Mt Vernon	Grey calcareous siltstone	Sevier?	B	62	9	N																					
688																												
689																												
690		Tan-brown interbedded slightly silty shale and poorly cemented medium grained gray or brown weathered sandstone	Tellico?	B	79	44	S																					
1m	Madisonville	Massive fine grained dark grey dolomite	Copper Ridge	B	47	36	SE																					
2m	Madisonville		Knox	B	37	71	S																					
3m	Madisonville		Chepultepec																									
10m	Madisonville	Dark gray sugary limestones	Knox or Conasauga																									
11m	Madisonville	Chert cemented sandstone																										
12m	Madisonville	Thinly bedded dark gray limestone float																										
13m	Madisonville	Green thinly bedded shale	Conasauga?	B(ot)?	89	71	N																					
14m	Madisonville	Dark gray calcareous siltstone	Blockhouse?	B	60	20	S																					
15m	Madisonville	Poorly cemented sandstone above calcareous		B	56	27	S																					
16m	Madisonville	Tan shale float	Athens?																									
17m	Madisonville	Tan gray calcareous shale	Athens	B	55	45	S																					
18m	Madisonville	Fine grained carbonate cemented sand stone	Toqua?	B	51	20	S																					
19m	Madisonville	Thinly bedded gray and tan calcareous siltstone	Athens	B	51	30	S																					
20m	Madisonville	Calcareous gray and tan shale and siltstone	Athens	B	66	33	S	C	65	66	S																	
21m	Madisonville	Tan gray thinly bedded shale	Athens	B(ot)?	57	85	N																					
22m	Madisonville	Tan/orange thinly bedded fissile shale	Athens	B	25	49	S																					
23m	Madisonville	Tan shale	Athens	B	50	43	S																					
24m	Madisonville	Tan slightly silty shale	Athens	B	50	42	S																					
25m	Madisonville	Sandy siltstone	Chapman Ridge	B	52	43	S																					
26m	Madisonville	Medium grained calcareous sandstone float																										
27m	Madisonville	Calcareous fine grained sandstone and siltstone	Toqua?	B	52	43	S																					
28m	Madisonville	Gray/tan calcareous siltstone	Athens	B	72	33	S																					
29m	Madisonville	Calcareous siltstone	Athens	B	65	32	E																					
30m	Madisonville	Tan/gray thinly bedded shale	Athens	B	79	40	S																					

Station No.	Terrace level	Comments
673		no good bedding - I say arkosic because it has occasional red grains of what could be feldspar
674		
674a		
675		might have soft sediment deformation, can't get a good top view, but thin beds have occasional waviness, not clean appearance. Red/brown siltstone just up hill suggests Bays - probably contact Bays and Sevier.
676		I have a feeling that it is part of a fold , but hard to tell, not enough outcrop
677		crinoids, bryozoans, brachiopods, looks like storm deposit. I'm not sure what rock to classify it as or what unit it is in.
678		
679		
680		
681		poorly exposed bedding
682		
683		grains are rounded to oval in shape - no obvious bedding
684		just below fossiliferous sandy sparry limestone with crinoids and brachiopod hash.
685		some deformation but not as nice as eastern outcrop.
686		more sandy layer is discontinuous, might be folded, might be soft sediment, could be Bacon Bend, but doesn't have siltstone. Soft sediment look might just be different expression.
687		
688		
689		
690		
1m		
2m		Fault? In Knox
3m		
10m		Hard to tell which unit, Rome or Conasauga, going down road to look at shale
11m		
12m		
13m		shale breaks off in what look like shale fibers, slightly silty, fault?
14m		
15m		
16m		
17m		Forms higher areas
18m		
19m		
20m		
21m		Bedding all along this portion of road nearly vertical to slightly overturned to 60se, maybe reason for small ridge
22m		
23m		
24m		
25m		
26m		found what look to be plant fossils in float
27m		
28m		
29m		
30m		

Station No.	Quadrangle	Rock type	Unit name	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Quaternary Unit Type
31m	Madisonville	Calcareous siltstone	Athens																													
32m	Madisonville	Weathered light gray sugary limestone chert nodules	Lenoir?																													
33m	Madisonville	Dolostone	Mascot?	B?	295	30	S																									
34m	Madisonville	Sandstone float with white non-calcareous cement	Mascot/ Kingsport																													
35m	Madisonville	Orange/tan shale float	Athens																													
36m	Madisonville	Tan/gray shale	Athens	B	50	54	S																									
37m	Madisonville	Tan/orange sandy shale	Athens	B	47	30	S																									
38m	Madisonville	Chert cemented sandstone	Mascot/ Kingsport																													
39m	Madisonville	Light gray aphanitic sparry dolostone	Mascot?																													
40m	Madisonville	Light gray fine grained medium bed thickness limestone	Mascot?	B	30	19	S																									
41m	Madisonville	Light gray fine grained limestone with chert nodule	Kingsport?	B	45	20	S																									
42m	Madisonville	Very fine grained sandstone float mixed in with chert float	Mascot/ Kingsport?																													
43m	Madisonville	Medium gray micritic limestone float																														
44m	Madisonville	Sugary dark gray dolostone float	Longview?																													
45m	Madisonville	Medium grained quartz sandstone float mixed with black and white banded chert nodules																														
46m	Madisonville	Silica cemented medium grained sandstone float with frosted quartz grains	Copper Ridge/ Chepultepec																													
47m	Madisonville	Fine grained well sorted tan sandstone	Copper Ridge/ Chepultepec																													
48m	Madisonville	Organic medium gray sugary dolostone	Copper Ridge																													
49m	Madisonville	Sandstone float																														
50m	Madisonville	Fine grained poorly cemented sandstone float																														
51m	Madisonville	Organic medium gray sugary dolostone, brecciated in places	Kingsport?	B	61	29	S																									
52m	Madisonville			B?	70	24	S																									
53m	Madisonville	Well rounded frosted quartz grains in white matrix - float																														
54m	Madisonville	Chert noduled dolomite with interbedded limestone	Kingsport?	B	60																											
55m	Madisonville	Tan shale float, chippy, mostly mud very little silt - carbonate		B	45	29	S																									
56m	Madisonville	Noncalcareous tan slightly silty shale	Chapman Ridge?	B	30	33	S																									
1TP	Tellico Plains		Rome	B	47	23	SE	B	25	10	NW	B	31	40	SE	Fr	2	67	E	Fr	79	74	S	Fr	314	70	N	FA	208	7	SW	
1.1TP		*Station 1TP -continued*		FA	54	9	SW	AP	23	58	NW	FA	213	9	SW	FA	221	65	SW	AP	21	84	W									
2TP	Tellico Plains	Red siltstone	Rome	B	49	51	N																									
3TP	Mt Vernon	Red siltstone	Rome	B	23	34	SE																									
4TP	Mt Vernon	Red siltstone	Rome	B	46	32	SE																									
5TP	Mt Vernon	Red siltstone	Maryville/ Maynardville	B	13	57	SE	B	23	26	SE																					
6TP	Mt Vernon	Thinly bedded silty carbonate	Knox	B	68	44	SE																									
7TP	Mt Vernon		Knox	B	48	38	SE	B	33	54	SE																					
8TP	Mt Vernon		Knox	B	36	25	E	B	38	62	E																					
9TP	Mt Vernon		Knox/Kingsport	B	41	43	E																									
10TP	Mt Vernon	Limestone	Chepultepec?	FA	37	4	NE	AP	37	81	SE	B	326	17	E																	
12TP	Mt Vernon		Knox	B	41	33	SE	B	49	13	SE																					
11TP	Mt Vernon		Knox	B	317	13	NE	AP																								
13TP	Mt Vernon			B	49	13	SE																									
14TP	Mt Vernon	Limestone	Knox	B	44	53	SE	B	43	50	SE																					
15TP	Mt Vernon		Knox	B	41	39	SE	B	49	28	SE																					
16TP	Mt Vernon			B	47	46	SE																									
17TP	Mt Vernon		Knox	B	41	33	SE																									

Station No.	Terrace level	Comments
31m		
32m		
33m		
34m		Mascot Kingsport contact?
35m		
36m		
37m		
38m		Big blocks, irregular, 1 foot by 1 foot square but not very sandy, will compare with other spot
39m		
40m		
41m		
42m		looks like mascot/Kingsport sandstone but hard to tell
43m		
44m		low ridges are probably dolostone, "valleys" are probably limestone
45m		
46m		
47m		Most likely contact between Chepultepec and Copper Ridge, relatively sandy soil also
48m		
49m		Walking along contact between Copper Ridge and Chepultepec
50m		
51m		Thickly bedded 2-6 ft
52m		
53m		
54m		Too hard to tell correct dip, Chepultepec with sandstone underneath, hard to tell no good markers.
55m		
56m		In stream bed - not exposed outside
1TP		Low amplitude synform first three bedding measurements north limb/south limb/north of main outcrop, lots of Joints and parasitic folds
1.1TP		
2TP		
3TP		
4TP		
5TP		
6TP		
7TP		
8TP		
9TP		
10TP		
12TP		
11TP		
13TP		
14TP		
15TP		
16TP		
17TP		Filled honey comb texture

Station No.	Quadrangle	Rock type	Unit name	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Quaternary Unit Type
18TP	Mt Vernon		Knox	B	11	17	E	B	80	2	S	B	39	37	SE																	
19TP	Mt Vernon		Knox	B	27	52	S	B	59	81	S	B	45	51	E																	
20TP	Mt Vernon		Knox	B	55	55	S	B	43	54	E	B	43	54	E																	
21TP	Mt Vernon		Chota?	B	53	68	SE																									
22TP	Mt Vernon	Brown calcareous cross bedded sandstone	Sevier	B	57	59	SE																									
24TP	Mt Vernon		Sevier	B(ot)	60	77	SE																									
25TP	Mt Vernon	Siltstone		B	43	9	NW																									
26TP	Mt Vernon			B	295	10	N																									
27TP	Mt Vernon		Sevier	B	35	39	S																									
28TP	Mt Vernon	Siltstone	Sevier	B	8	7	NW																									
29TP	Mt Vernon	Shale/siltstone	Sevier	B	46	18	E																									
30TP	Mt Vernon	Shale	Sevier	B	60	9	S																									
31TP	Mt Vernon	Sandy limestone		B	323	4	SW																									
32TP	Mt Vernon		Sevier?	B	20	17	NW																									
33TP	Mt Vernon	Shale		B	15	7	W																									
34TP	Mt Vernon	Tan weathered, gray/buff fresh thinly bedded fissile calcareous shale		B	50	23	S																									
35TP	Mt Vernon	Tan weathered, gray/buff fresh thinly bedded fissile calcareous siltstone	Athens?	B	31	45	S																									
36TP	Mt Vernon	Tan/gray thinly bedded fine grained sandstone siltstone	Chapman Ridge	B	60	20	S																									
37TP	Mt Vernon	Tan fine grained sandstone	Chapman Ridge	B	65	35	S																									
38TP	Mt Vernon	Tan/gray, thin to medium bedded, fine grained sandstone	Athens	B	50	30	S																									
39TP	Mt Vernon	Tan/brown thinly bedded calcareous siltstone interbedded with shale	Athens	B	54	53	S																									
40TP	Mt Vernon	Tan/gray thinly bedded calcareous siltstone	Chota?	B	75	17	S																									
41TP	Mt Vernon	Brick red, medium to thick bedded calcareous fine grained sandstone	Sevier?	B	40	22	N																									
42TP	Mt Vernon	Gray/tan calcareous coarse grained sandstone		B	40	70	SE																									
43TP	Mt Vernon	Dark gray massive limestone																														Alluvium
44TP	Mt Vernon	Light gray limestone with silty stringers		B	40	37	S																									
45TP	Mt Vernon	Dark gray slightly laminated sandy limestone	Chapman Ridge	B(ot)	60	70	S																									
46TP	Mt Vernon	Tan siltstone with occasional sandy beds	Athens or Sevier	B(ot)	67	72	SE																									
47TP	Mt Vernon	Tan, thinly to medium thickness shale	Sevier	B(ot)	65	45	S																									
48TP	Mt Vernon	Tan thinly bedded shale	Sevier	B	27	12	N																									
49TP	Mt Vernon	Thinly bedded calcareous siltstone	Sevier	B	315	4	W																									
50TP	Mt Vernon	Thinly bedded calcareous siltstone	Sevier	B	70	15	S																									
51TP	Mt Vernon	Tan/gray medium to thick bedded calcareous siltstone	Sevier	B	54	24	W																									
52TP	Mt Vernon	Cross bedded fine grained calcareous sandstone	Sevier	B	85	10	N																									
53TP	Mt Vernon	Gray fine grained calcareous sandstone	Sevier?	B	45	20	N																									
54TP	Mt Vernon	Gray calcareous fine grained sandstone with occasional resistant sandy ribbons	Sevier	B(ot)	35	85	S																									
55TP	Mt Vernon	Tan weathered, gray/buff fresh thinly bedded fissile calcareous shale	Sevier	B	45	80	N																									
56TP	Mt Vernon	Tan thinly bedded shale	Sevier	B	50	90																										
57TP	Mt Vernon	Tan thinly bedded shale	Sevier	B(ot)	55	85	S																									
58TP	Mt Vernon	Tan thinly bedded shale	Sevier	B	55	90																										
59TP	Mt Vernon	Gray calcareous medium grained sandstone	Sevier	B(ot)	65	80	S																									
60TP	Mt Vernon	Tan weathered, gray/buff fresh thinly bedded fissile calcareous shale	Sevier	B	40	90																										
61TP	Mt Vernon	Gray shale	Lenoir?	B	45	24	S																									
62TP	Mt Vernon	Dark gray thickly bedded micritic limestone	Toqua	B(ot)	55	35	S																									

Station No.	Terrace level	Comments
18TP		
19TP		Jen says karst sinkhole breccia, second bedding measurement is near vertical bedding, third measurement between stations 19 and 20
20TP		first two outside of fold
21TP		
22TP		
24TP		near last river bend
25TP		
26TP		
27TP		
28TP		
29TP		
30TP		
31TP		
32TP		
33TP		
34TP		thin fossil layer
35TP		
36TP		
37TP		
38TP		chippy, in some places nearly green
39TP		can be green in places
40TP		No cross bedding? Is ferruginous sandstone more prevalent further south? Is Chota just first red s.s. in Sevier? Holston equivalent
41TP		
42TP		
43TP	880-900	Tan colored sandstone/quartzite, pebbles well rounded, moderately sorted, 5-7 cm in length, 10-20/sq meter, 2's and 3's, occasional chert
44TP		anticline in Knox/Lenoir? Rather broad, trend n60E
45TP		brown soil
46TP		
47TP		
48TP		
49TP		
50TP		
51TP		
52TP		
53TP		
54TP		
55TP		near fault if one exists
56TP		
57TP		
58TP		outcrop too poor to get good strike and dip, would guess nearly vertical given orientation of nearby beds
59TP		
60TP		David O'Dell, farmer
61TP		organic smelling
62TP		Lenoir below it? Pretty sure it's Lenoir, has snail shells

Station No.	Quadrangle	Rock type	Unit name	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Quaternary Unit Type
63TP	Mt Vernon	Fine grained poorly cemented sandstone	Toqua																													
64TP	Mt Vernon	Fine grained poorly cemented sandstone	Athens																													
65TP	Mt Vernon	Tan shale float	Athens?																													
66TP	Mt Vernon	Red brown sandstone float	Athens																													
67TP	Mt Vernon	Tan shale float	toqua?																													
68TP	Mt Vernon	Tan dirty sandstone																														
69TP	Mt Vernon	Tan shale float	Athens																													
70TP	Mt Vernon	Dark red-purple sandstone	Chota? Tellico?	B(ot)	55	60	S																									
71TP	Mt Vernon	Medium bedded fine grained sandstone with silty layers	Chota? Athens?	B(ot)	60	70	S																									
72TP	Mt Vernon	Red pink fossiliferous limestone	Chota/ Holston	B(ot)	60	70	S																									
73TP	Mt Vernon	Gray dolomite	Mascot?	B	65	21	S																									
74TP	Mt Vernon	Dark grey dolomite																														
75TP	Mt Vernon	Medium grey sugary dolomite with some white chert		B	25	20	N																									
76TP	Mt Vernon	Dark grey limestone	Lenoir?	B?	280	32	S																									
77TP	Mt Vernon	Dark grey limestone	Lenoir	B	310	10	E																									
78TP	Mt Vernon	Dark gray limestone with calcite veins	Lenoir	B	40	11	N																									
79TP	Mt Vernon	Dark gray limestone with silt/clay lenses		B	15	15	W																									
80TP	Mt Vernon	Dark gray limestone		B	15	60	W																									
81TP	Mt Vernon	Dark gray limestone with silty layers, maybe stylolytes	Lenoir?	B	50	37	S																									
82TP	Mt Vernon	Dark grey, thickly bedded micritic limestone	Lenoir	B	45	34	S																									
83TP	Mt Vernon	Sugary medium thick bedded medium gray dolomite	Mascot?	B(ot)	56	44	S																									
84TP	Mt Vernon	Dark gray micritic limestone	Lenoir	B(ot)	55	22	S																									
85TP	Mt Vernon	Thick to medium bedded, fine to medium grained s.s with interbedded silt/shale	Sevier?	B	68	8	N																									River Bank
86TP	Mt Vernon	Thinly bedded gray/tan(weathered) calcareous siltstone/fine grained sandstone	Sevier?	B	70	37	S																									
87TP	Mt Vernon	Tan siltstone	Sevier?	B	30	10	N																									
88TP	Mt Vernon	Tan weathered, gray/buff fresh thinly bedded fissile calcareous shale	Sevier?	B(ot)	65	74	S																									
89TP	Mt Vernon	Slightly sandy sparry gray limestone with some fossil hash	Chota/Holston	B(ot)	60	69	S																									
90TP	Mt Vernon	Highly weathered sandstone with interbedded tan shale	Chota?	B(ot)	65	59	S																									
91TP	Mt Vernon	Tan, thinly bedded shale	Athens	B(ot)	75	64	S																									
92TP	Mt Vernon	Calcareous medium grained sandstone float	?																													
93TP	Mt Vernon	tan fissile thinly bedded shale, kinda shiny	Athens	B	80	54	S																									
94TP	Mt Vernon	Thinly bedded shale	Sevier	B	50	90																										
95TP	Rafter	Sparry brown/gray limestone with some gray coarse sandy limestone to south	Chota?	B	65	73	N																									
96TP	Rafter	Gray fine grained calcareous sandstone		B	75	74	N																									
97TP	Rafter	Gray fresh, tan weathered calcareous siltstone	Sevier	B	70	60	N																									
98TP	Rafter	Mildly cross bedded medium grained sandstone	Sevier	B	50	20	N																									
99TP	Mt Vernon	Tan/orange shale float	Sevier?																													
100TP	Mt Vernon	Shale	Athens	B(ot)	85	76	S																									
101TP	Mt Vernon	Tan and gray shale	Athens	B	85	44	S																									
102TP	Mt Vernon	Light gray dolomite	Lenoir?	B	55	35	S																									
103TP	Rafter	Dark gray micritic limestone with few fossils	Lenoir	B	60	64	S																									
104TP	Rafter	Sandstone, almost quartzite	Chilhowee																													

Station No.	Terrace level	Comments
63TP		picture is of fault ridge, sandstone and shale form top, gray outcrop is limestone in footwall, picture is taken facing south standing on toqua in footwall, fault itself is buried
64TP		float
65TP		Tellico (more likely) or Chota (not yet)
66TP		
67TP		
68TP		from shore on west, last occurrence of limestone, probably overturned, probably Lenoir, not visible on opposite bank
69TP		can't tell extent of fault due to lack of exposure
70TP		don't see cross beds but outcrop is covered in moss, picture 9
71TP		looks more like Chota than Tellico but wrong grain size
72TP		not many fossils in sample
73TP		
74TP		no idea where I am in section
75TP		Bedding is questionable
76TP		bedding measured on a silt ribbon
77TP		in hinge of antiform
78TP		Black snake just charged me
79TP		
80TP		
81TP		
82TP		
83TP		
84TP		I think the fault is covered in most places with sandstone appearing mainly as float at this location
85TP		trench digging dug for 45 minutes in bank along Tellico, very sandy with some clay, pretty coherent, Dug into bank down to water table, not much structure to sediment, pictures 18,19,20, show lack of layering, bank too shelf like to make digging worth while, try more walls
86TP		
87TP		nearly horizontal
88TP		Bedding along road is wavering between overturned and not overturned with steep dips
89TP		
90TP		
91TP		
92TP		
93TP		expect fault anytime now
94TP		vertical bedding with some folding and abrupt bedding changes=faults went in water right after this!
95TP		bedding is difficult
96TP		
97TP		
98TP		has numerous dark coarse grained stringers with some linear upper surfaces of crossbeds
99TP		
100TP		
101TP		
102TP		
103TP		
104TP		float, maybe from hw of great smokey fault

Station No.	Quadrangle	Rock type	Unit name	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Quaternary Unit Type
105TP	Rafter	Light colored silica cemented sandstone	Chilhowee																													
106TP	Rafter	Tan thinly bedded shale	Athens	B	70	63	S																									
107TP	Rafter	Tan thinly bedded siltstone	Athens	B	70	80	N																									
108TP	Rafter	Highly weathered brown sandstone	Chota? Tellico?																													
109TP	Rafter	Red brown weathered sandstone	?	B(ot)	60	75	S																									
110TP	Rafter	Tan to gray thinly bedded shale	Athens?	B(ot)?	50	84	S																									
111TP	Rafter	Gray and pink dolostone	Mascot?																													
112TP	Rafter	Gray dolostone																														
113TP	Rafter	Yellow weathered siltstone	Conasauga/ Nolichucky	B	5	86	E	B	17	47	E																					
114TP	Rafter	Brown/orange fine grained sandstone	unknown																													
115TP	Rafter	Red thinly bedded siltstone	Rome?	B	65	23	S																									
116TP	Rafter	Tan fine grained poorly cemented sandstone																														
117TP	Rafter	Brick red/brown interbedded siltstone and shale	Rome?	B	3	65	E																									
118TP	Rafter	Tan shale float	Athens?																													
119TP	Rafter	Dark gray sugary limestone float and orange shale chips																														
120TP	Rafter	Tan/green thinly bedded fissile shale	Athens	B(ot)?	40	45	S																									
121TP	Rafter	Poorly cemented medium grained, orange quartz-grained sandstone float	Toqua?																													
122TP	Rafter	Tan and gray thinly bedded shale/silty shale	Athens	B(ot)	30	65	S																									
123TP	Rafter	Calcareous siltstone	Athens	B	39	88	N	B	70	55	S																					
124TP	Rafter	Thinly bedded gray/tan shale	Athens	B(ot)	45	65	S																									
125TP	Rafter	Red/orange thinly bedded shale	Chapman Ridge	B(ot)	60	75	S																									
126TP	Rafter	Sevier Shale	Sevier	B	55	24	N																									
127TP	Rafter	Highly weathered red shale with tan thin bedding	Sevier	B	67	27a	S																									
128TP	Rafter	Tan micaceous shale-can't find fossils	Athens?/ Conasauga?	B	57	37	S																									
129TP	Rafter	Gray green shale/slate	Conasauga?/ Chilhowee?	B	45	80	S																									
1V	Mt Vernon	Thinly bedded calcareous silty shale/ interbedded fine grained sandstone		B	52	24	S																									
2V	Mt Vernon	Tan/gray calcareous sandy and silty shale, thinly bedded		B	49	20	S																									
3V	Mt Vernon	Medium grained quartz ss, calcareous, sub- to well-rounded qtz grains	Chapman Ridge	B	52	32	S																									
4V	Mt Vernon	Grey calcareous fine-grained ss/siltstone thin to medium bedded	Chapman Ridge	B	52	29	S																									
5V	Mt Vernon	Dk. grey fossiliferous sandy ls alternating w/ calcareous ss		B	46	13	S																									
6V	Mt Vernon	Grey calcareous ss with lentils of siltstone and thin layers of coarse sand	Och?																													
7V	Mt Vernon	Tan and red siltstone saprolite with coarse ss stringers - red soil	Sevier																													
8V	Mt Vernon	Dark brick red crossbedded medium grained poorly cemented ss	Och	B	55	28	S																									
9V	Mt Vernon	Med grey calcareous ss scattered small calcite veins	Sevier	B	26	44	S																									
10V	Mt Vernon	Silty chips, silty calcareous shale																														
11V	Mt Vernon	Red and tan, thinly bedded silty/very fine sandy shale	Sevier	B	60	20																										
12V	Mt Vernon	Silty shale float - just west		B	40	10	S																									
13V	Mt Vernon	Very fine sandy shale along this stretch w/ silty shale to shale on either side																														
14V	Mt Vernon	Red and tan slightly silty weathered shale	Sevier	B	30	22	S																									
15V	Mt Vernon	Tan/gray calcareous thinly bedded v. fine grained sandstone/ sandy siltstone		B	58	20	S																									
16V	Mt Vernon	Dark red/brown uncemented fine grained sandstone float/soil																														
17V	Mt Vernon	Tan silty shale float/soil																														

Station No.	Quadrangle	Rock type	Unit name	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Quaternary Unit Type
18V	Mt Vernon	Red fine-grained thinly bedded calcareous ss - weathers grey		B	42	24	S																					
19V	Mt Vernon	Calcareous silty shale float	Chapman Ridge - didn't see any good Chota																									
20V	Mt Vernon	Tan/grey calcareous silty shale		B	45	22	S																					
21V	Mt Vernon	Medium-grained medium-bedded calcareous ss. sub-to well-rounded grains		B	40	29	S																					
22V	Mt Vernon	Tan and grey, thickly bedded, fine grained calcareous ss		B	65	34	S																					
23V	Mt Vernon	Tan and grey - thinly bedded, very fine grained calcareous siltstone		B	49	29	S																					
24V	Mt Vernon	Tan thinly bedded silty shale	Chapman Ridge	B	49	47	S																					
25V	Mt Vernon	calcareous shale float	Blockhouse?																									
26V	Mt Vernon	Tan, poorly cemented, thinly bedded, very fine grained ss	Athens	B	69	27	S																					
27V	Mt Vernon	Tan interbedded thick shale and medium thickness very fine grained ss.		B	44	29	S																					
28V	Mt Vernon	No outcrop - see comment																										
29V	Mt Vernon	Grey/lt. grey dolomite float	not sure																									
30V	Mt Vernon	Carbonate - guessing on strat location	Mascot? or Chepultepec?	B	50	25	S																					
31V	Mt Vernon	Light grey sparry fine-grained limestone - thin to medium B			58	31	S																					
32V	Mt Vernon	1 big piece (10-15 cm) silica cemented ss float - limestone above	Mascot/ Kingsport maybe close by	B	55	29	S																					
33V	Mt Vernon	Light grey limestone		B	75	28	S																					
34V	Mt Vernon	Grey calcareous siltstone with coarse grained sand stringers interbedded w/ shale/v. fine ss.		B	15	21	N																					
35V	Mt Vernon	Tan calcareous thinly bedded siltstone		B	27	19	N																					
36V	Mt Vernon	Tan/grey calcareous siltstone with some soft sediment deformation	Bacon Bend	B	7	11	W																					
37V	Mt Vernon	Brick red calcareous siltstone/very fine grained ss	Bays Fm.	B	15	19	W																					
38V	Mt Vernon	Brick red siltstone - thinly bedded/VFG ss.		B	358	9	W																					
39V	Mt Vernon	Brick red very. fine-grained calcareous ss. with good cleavage. Med. bed thickness		B	29	15	N	C	32	79	E																	
40V	Mt Vernon	Interbedded brick red calcareous ss. & siltstone/silty shale		B	340	5	E	FA	215	45																		
41V	Mt Vernon	Grey thinly bedded calcareous siltstone in stream		B	25	12	S																					
42V	Mt Vernon	Calcareous ss/siltstone medium thickness bedding	Bays	B	68	9	S																					
43V	Mt Vernon	Cleaved calcareous red siltstone	Bays	B	83	11	S	C	82	88	S																	
44V	Mt Vernon	Calcareous siltstone																										
45V	Mt Vernon	Calcareous very fine grained sandstone		B	35	14	S																					
46V	Mt Vernon	Grey/tan medium thick bedded calcareous siltstone	Sevier?	B	70	17	S																					
47V	Mt Vernon	Tan thinly bedded calcareous shale	Sevier	B	35	31	S																					
48V	Mt Vernon	Grey/tan thinly bedded silty shale		B	65	25	S																					
49V	Mt Vernon	Tan and red shale interbedded with red siltstone/VFG ss.		B	60	26	S																					
50V	Mt Vernon	More interbedded tan and red shale/silty shale and VFG ss.		B	73	24	S																					
51V	Mt Vernon	Tan siltstone with soft sediment deformation-red siltstone of Bays above	Bacon Bend	B	61	22	S																					
52V	Mt Vernon	Brick red calcareous silty shale w/ medium bedding and medium cleavage development		B	55	15	S	C	24	87	S																	

Station No.	Terrace level	Comments
18V		near bottom of series
19V		
20V		
21V		just north on road about 40 ft - coarse gained cross bedded 2 ft thick possible small channel deposit
22V		
23V		
24V		
25V		
26V		
27V		
28V		chert in soil - probably crossed into Lenoir on hill, not sure what I'm in now as there is no outcrop
29V		not sure what formation
30V		
31V		
32V		
33V		massive outcrop , cant' get good sample off.
34V		
35V		
36V		
37V		
38V		
39V		
40V		Looks like tidal flat with channels - all calcareous - near hinge or more likely IN hinge. Picture 6 - Bedding?? Picture 7 - accommodation folding - fault related fold. Fault dips to N, probably still in southern syncline arm. See sketch of fold for bedding/fold axis orientations.
41V		obviously folded but mostly under water
42V		
43V		
44V		too little to tell if it's Bacon Bend. Can't see soft sediment deformation
45V		
46V		
47V		
48V		
49V		
50V		
51V		
52V		

Station No.	Quadrangle	Rock type	Unit name	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Quaternary Unit Type
53V	Mt Vernon	Calcareous siltstone and interbedded ss. - medium thickness bedding	Bays	B	55	10	S																					
54V	Mt Vernon	Calcareous VFG ss./siltstone		B	60	7	N																					
55V	Mt Vernon	Calcareous ss.	Bays	B	50	7	N																					
56V	Mt Vernon	Calcareous siltstone/ silty shale and sandstone																										
57V	Mt Vernon	Red calcareous siltstone - thinly bedded		B	53	20	N																					
58V	Mt Vernon	Red sandstone layers																										
59V	Mt Vernon	Tan and red shale looks like Sevier	Sevier	B	85	14	N																					
60V	Mt Vernon	Tan and red interbedded shale and siltstone		B	70	74	N																					
61V	Mt Vernon	Gray thinly bedded shale	Sevier?	B(ot)	57	84	S																					
62V	Mt Vernon	Tan/gray shale	Sevier?	B(ot)	60	85	S																					
63V	Mt Vernon	Tan grey shale	Sevier	B(ot)	58	86	S																					
64V	Mt Vernon	Tan shale	Sevier?	B	59	81	N																					
65V	Mt Vernon	Grey calcareous thinly bedded siltstone	Sevier	B	45	50	N																					
66V	Mt Vernon	Grey/red calcareous ss - can't tell bedding																										
67V	Mt Vernon	Tan and gray calcareous siltstone		B	61	14	S																					
68V	Mt Vernon	Thinly bedded calcareous siltstone		B	15	15	S	C	52	66	S	B	20	20	N													
69V	Mt Vernon	Thinly bedded calcareous shale		B	330	29	W																					
70V	Mt Vernon	Thinly layered thickly bedded red brown calcareous sandy siltstone	Bays	B	345	8	E																					
71V	Mt Vernon	Tan and grey thinly bedded calcareous VFG ss.		B	85	12	S																					
72V	Mt Vernon	light gray carbonate with thickly bedded sparry calcite and tan more resistant stringers	OCk	B	60	37	N																					
73V	Mt Vernon	Tan poorly cem. med. grnd. sub< to sub-rounded quartz/feldspar arkosic ss. float near tan/orange fissile silty shale	Conasauga? Athens																									
74V	Mt Vernon		Quaternary																									Terrace deposit
75V	Mt Vernon	Tan grey thinly bedded (1-2cm) weathered shale		B(ot)?	22	29	S	B	57	88	N																	
76V	Mt Vernon	Tan grey thinly bedded shale		B	46	24	S																					
77V	Mt Vernon	Grey tan shale slightly calcareous	Chapman Ridge	B	5	24	E																					
78V	Mt Vernon	Tan thinly bedded shale		B	60	85	N																					
79V	Mt Vernon	Tan thinly (1-2 mm) bedded shale		B	59	86	N																					
80V	Mt Vernon	Fold in thinly bedded shale	Athens?																									
81V	Mt Vernon	Thinly bedded tan grey shale	Athens?	B	24	27	N																					
82V	Mt Vernon	Tan thinly bedded silty shale		B	49	71	S																					
83V	Mt Vernon		Athens					FA	54	7		AP	60	46	E	FA	55	9										
84V	Mt Vernon	Tan and grey calcareous siltstone		B	89	12	N																					
85V	Mt Vernon	Folded calcareous siltstone		B	40	8	N	B	40	49	N																	
86V	Mt Vernon	Tan and grey calcareous siltstone		B	62	89	N																					
87V	Mt Vernon	Thinly bedded dull tan calcareous siltstone interbedded w/ shale	Athens	B	54	87	N																					
88V	Mt Vernon	Tan and grey shale with prismatic chips	Athens?	B(ot)	25	35	S																					
89V	Mt Vernon	Tan and grey thinly bedded calcareous shale		B	50	73	N																					
90V	Mt Vernon	Thinly bedded calcareous shale		B	55	76	N																					
91V	Mt Vernon	Red brown float and soil, medium grained subrounded to rounded hematite cemented sandstone	Chota	B	37	15	N																					
92V	Mt Vernon	Red brown thin to medium bedded sandstone		B(ot)	70	80	S																					
93V	Mt Vernon	Tan and grey thinly bedded calcareous silty shale		B	56	15	N																					
94V	Mt Vernon	Thickly bedded fine grained calcareous sandstone interbedded w/ calcareous siltstone		B	57	11	N																					

Station No.	Terrace level	Comments
53V		
54V		
55V		
56V		road is graded same as dip slope
57V		100 ft, down road, folded thinly bedded tan siltstone, only about 4 ft thick - looks like Bacon Bend but thinner, more folded. Might just be folded layer in Bays.
58V		Red ss. Layers 1-2 m thick with some thinner layers with what look to be only vein material remaining & acting as support columns (see sketch)
59V		
60V		small fold? Can't see any outcrop nearby that doesn't have this orientation
61V		
62V		
63V		
64V		
65V		
66V		
67V		I don't get it - part of fold parasitic?
68V		[last measurement] near road
69V		
70V		
71V		
72V		probably moved a lot
73V		
74V	940 ft	70's of cobbles/ sq. meter soil color 10YR 5/6 moderate brown. Cobbles 8-10 cm (in diam.)??? Vein quartz, quartzite, some sandstone - well rounded to subrounded. 1's and 2's - occasional 3
75V		tan chippy shale float. Overturned, faulted, nose of fold. 50 m from T in road bedding is vertical to dipping slightly to NW
76V		20 m down hill
77V		bedding of tan moderate in base of roadside channel.
78V		
79V		
80V		
81V		
82V		
83V		folded zone: amplitude about 1 ft, wavelength about 3-4 ft. verge to North, hard to tell if this is a faulted unit or not, so little exposure outside of gully
84V		
85V		
86V		
87V		
88V		
89V		
90V		
91V		can't find any outcrop - all shale
92V		
93V		
94V		sandier as I move Northwest

Station No.	Quadrangle	Rock type	Unit name	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Kind	S/T	P/D	Dir.	Quaternary Unit Type
95V	Mt Vernon	Grey-weathering tan, medium bedded (2-3 ft) sandy, fossiliferous limestone		B	275	25	S																									
96V	Mt Vernon	Tan calcareous shale float and some on surface		B	295	17	N																									
97V	Mt Vernon	Tan and orange siltstone		B	277	15	N																									
98V	Mt Vernon	Grey thinly bedded calcareous siltstone		B	290	10	N																									
99V	Mt Vernon	Tan orange thinly bedded (1-2 mm) silty shale	Sevier	B	84	76	N																									
100V	Mt Vernon	Tan orange silty shale	Sevier	B	62	76	N																									
101V	Mt Vernon	Tan orange thinly bedded shale	Sevier	B(ot)	46	80	S																									
102V	Mt Vernon	Tan orange thinly bedded shale	Sevier	B(ot)	56	85	S																									
103V	Mt Vernon	Tan orange thinly bedded silty shale float	Sevier																													
104V	Mt Vernon	Tan gray thinly bedded calcareous shale &		B(ot)	59	70	S																									
105V	Mt Vernon	Hematite cemented, cross bedded fine to medium grained subrounded to rounded ss.	Chota	B(ot)	83	65	S																									
106V	Mt Vernon	Pale tan thinly bedded shale		B	50	76	N																									
107V	Mt Vernon	Tan calcareous shale	Chapman Ridge?	B	55	49	S																									
108V	Mt Vernon	Tan silty shale - fractured up																														
109V	Mt Vernon	Carbonate limestone(?)	Knox?	B	79	25	S																									
110V	Mt Vernon	Tan shale float?																														
111V	Mt Vernon	Red soil with chert-light tan chert float	probably Knox																													
112V	Mt Vernon	Chips of thinly bedded tan orange shale w/ occasional silty bit																														
113V	Mt Vernon	Tan orange to slightly green thinly bedded highly cleaved and fractured shale w/ occasional silty portions	Athens or Conasauga	B	47	39	E	C	47	87	N																					
114V	Mt Vernon	Lt. br./tan F2M-grnd well rounded poorly cem., thick bedded occas. arkosic ss. Interbed. w/ thin bed. sh. & siltstone		B	47	18	N																									
115V	Mt Vernon	Tan ??? med. grained ss. w/ occasional siltstone		B	26	15	S																									
116V	Mt Vernon	Tan medium grained med.-to thick-bedded (4 cm to 31 cm) folded sandstone better cemented than previous		B	50	60	N	B	35	45	S	FA	57	7																		
117V	Mt Vernon	Orange interbedded fine grained sandstone, siltstone and shale		B	10	17	W																									
118V	Mt Vernon	Poorly cemented thick to medium bedded rounded medium grained sandstone		B	50	17	S	B	5	12	S	B	20	39	S																	
119V	Mt Vernon	Tan and grey shale		B	20	39	S																									
120V	Mt Vernon	Orangey tan thinly bedded fine grained sandstone in drainage ditch		B(ot)?	45	79	S																									
121V	Mt Vernon	Dove gray micritic thick bedded limestone. Bouldery outcrop style	Lenoir?	B	4	15	S																									
122V	Mt Vernon	Limestone	Lenoir	B	0	25	E																									
123V	Mt Vernon	Occasional thin fossil beds	Lenoir?	B	25	22	S																									
124V	Mt Vernon			B	345	20	E																									
125V	Mt Vernon	Calcareous gray shale	Blockhouse?	B	60	25	N																									
126V	Mt Vernon	Thin carbonate shale	Blockhouse?	B	57	30	N																									
127V	Mt Vernon			B	60	33	N																									

Station No.	Terrace level	Comments
95V		mostly fossil hash: crinoids, bryozoan pieces, burrows? Occasional brachiopods.
96V		
97V		
98V		98Va - maybe down road, gray thickly bedded calcareous sandstone - Sevier
99V		
100V		
101V		
102V		
103V		
104V		
105V		jen comment - says Chota - but is in middle of Chapman ridge ridge
106V		
107V		the sandy layers don't seem as predominant here as they did in the northeast limb.
108V		no clear bedding of folding for that matter - hard to tell what is going on. Lots of arkosic ss. float like 73V
109V		
110V		I'm confused - maybe repeated Knox/Athens
111V		no good exposure
112V		All float - no good outcrop, but crossed contact with Knox to East
113V		question about what is bedding and what is cleavage
114V		looks like old river or stream channel deposit 6-10 ft wide & 2 ft thick. Good cross beds.
115V		probably same as last layer - less exposure, may be ???? For lack of cross beds and more interbedded siltstone and shale. Slight change in ???? Could be related to ???? ??? we saw walking uphill
116V		
117V		
118V		bedding can't tell at this outcrop, looks like it's dipping south. 1st bedding: ss, 2nd bedding: shale, 3rd bedding: shale.
119V		fractures too bad to get good cleavage
120V		
121V		
122V		fine sandy layer not too far away
123V		
124V		hard to say from across the fence, maybe nose of fold?
125V		
126V		
127V		hard to tell what formation

VITA

Chris Whisner was born in Rochester, Michigan October 28th, 1971. He grew up in Saginaw, Michigan attending Westdale Elementary School moved to Al-Khobar, Saudi Arabia between the years 1980-1983 and attended Dhahran Academy. He returned to Saginaw where he attended Chippewa Middle School and Douglas MacArthur High School until 1987 when he moved to Caledonia, Michigan. He graduated from Caledonia High school in 1990. He attended Western Michigan University in Kalamazoo, Michigan beginning in 1990 and received a B. S. in geology in 1994 and a M. S. in Geology in 1998. From there he moved to Knoxville, Tennessee and received a PhD. in Geology in 2005. Chris is currently doing post doctoral research at the University of Tennessee.